MAPPING TOGETHER

A Guide to Monitoring Forest and Landscape Restoration Using Collect Earth Mapathons

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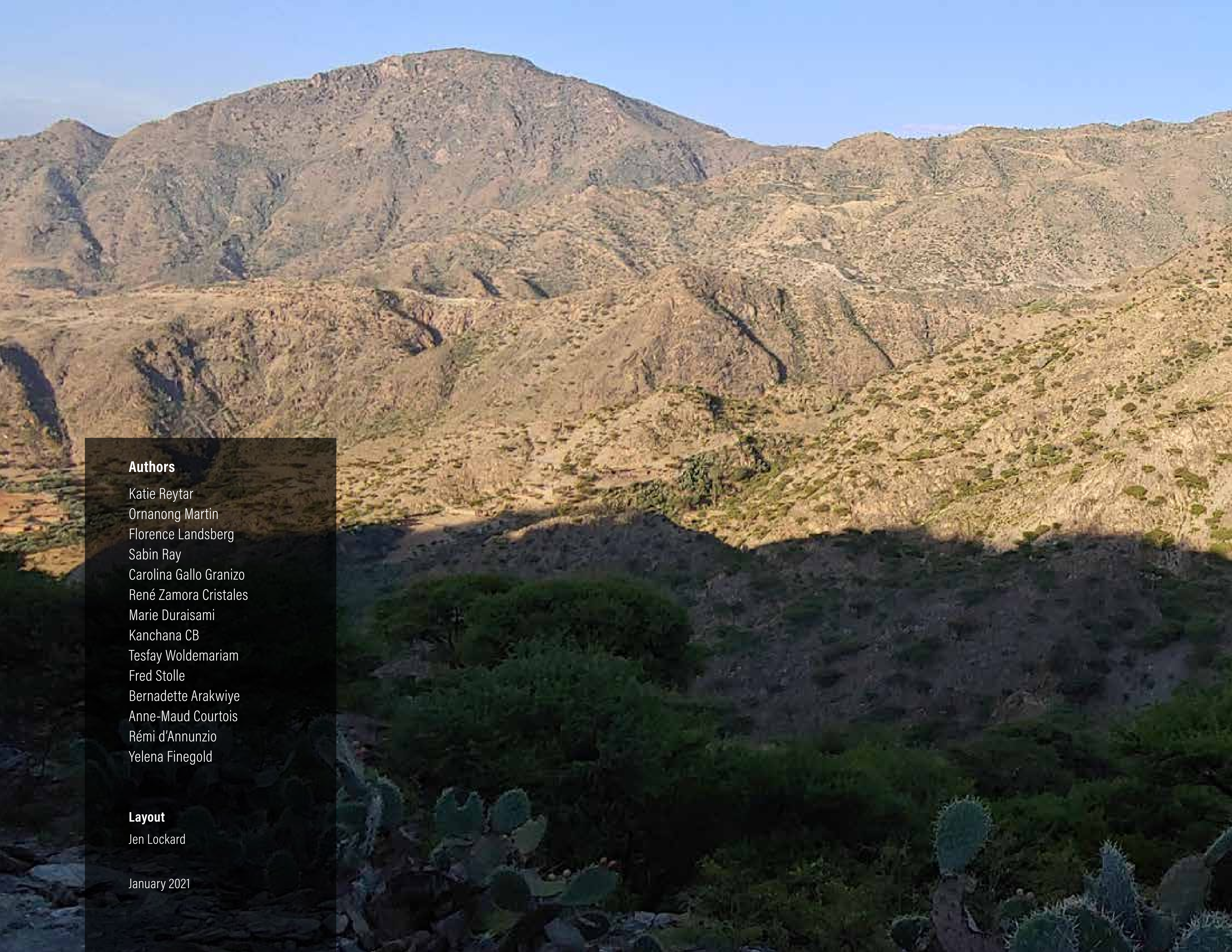

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January 2021

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LIST OF ABBREVIATIONS

AFR100: African Forest Landscape Restoration Initiative

CRGE: Climate Resilient Green Economy (Ethiopia)

ECCA30: Forest landscape restoration initiative in Europe, Caucasus, and Central Asia

FAO: Food and Agriculture Organization of the United Nations

FRA: Global Forest Resources Assessment (FAO Global Program)

GTP: Growth and Transformation Plan (Ethiopia)

IPCC: Intergovernmental Panel on Climate Change

NGO: nongovernmental organization

NRSC: National Remote Sensing Centre (India)

REDD+: Reducing Emissions from Deforestation and forest Degradation (the + stands for fostering conservation, sustainable management of forests, and enhancement of forest carbon stocks)

SEPAL: System for Earth Observations, Data Access, Processing & Analysis for Land Monitoring

WRI: World Resources Institute

GLOSSARY

Agroforestry: Integration of trees with cropland or other agricultural systems.

Baseline: A documented starting point, or point of departure, that acts as a control against which to measure progress on restoration activities.

Biophysical: For this guidebook, *biophysical* refers to the physical aspects of the landscape (e.g., land use/land cover, tree cover) that can be detected by visually interpreting satellite imagery.

Bunds: Earthen or stone structures built along contour lines in agricultural lands that increase water infiltration, enhance soil moisture, and prevent erosion (Waelti and Spuhler 2010).

Collect Earth: A desktop-based data collection tool that integrates into a Google Earth interface where users can analyze high- and very-high-resolution satellite imagery to monitor the state and change of land use/land cover. Collect Earth is part of the Open Foris suite of tools developed by the Food and Agriculture Organization of the United Nations.

Collect Earth Online (https://collect.earth/): A web-based data collection tool where users can analyze high- and very-high-resolution satellite imagery to monitor the state and change of land use/land cover. It performs similar functions as the desktop version of Collect Earth but is fully integrated into a web-based platform. Collect Earth Online is part of the Open Foris suite of tools supported by the Food and Agriculture Organization of the United Nations.

Control Points: For the purposes of this guidebook, *control points* refers to the points (dots) inside the sample plot, which are spaced at customizable intervals and help estimate percent coverage of certain features (e.g., trees) inside the sample plot. In Collect Earth, the control points are the small yellow boxes (dots) inside the larger yellow box that is the sample plot (see Figure 2).

Forest and Landscape Restoration: A process that aims to regain ecological functionality and enhance human well-being across degraded landscapes (Lamb 2014; Chazdon et al. 2015; Besseau et al. 2018). Landscapes may be forested or non-forested.

Groundtruthing: Validating assessed data points by comparing them to observations in the field.

Indicator: A variable used to represent change or the attainment of a goal (e.g., change in crop yield). An indicator may be a composite measure made up of multiple metrics.

Land Use/Land Cover: *Land cover* is defined as "the observed biophysical cover on the Earth's surface," while *land use* is "characterized by the arrangements, activities people undertake in a certain land cover type to produce, change or maintain it" (Di Gregorio 2005). Throughout this guidebook, we commonly refer to both terms together because the biophysical cover and people's use of the land are often intermingled to identify and classify various types. For example, a collection of trees can be identified, initially, as a forest (land cover), but if those trees form a certain pattern, they can be identified as an orchard or urban park (land use). Therefore, to acknowledge these distinct definitions while remaining comprehensive as to the various types that can be identified as part of a data collection exercise, we include both terms together in this guidebook.

Landscape: For this guidebook, a landscape is defined as "a geographic area in which variables of interest are spatially heterogeneous. The boundary of a landscape may be delineated based on geographic, ecological, or administrative units (e.g., a watershed, an urban area, or a county) that are relevant to the research questions and objectives" (Wu 2013).

Mapathon: A coordinated group mapping event where participants are invited to collectively and intensively collect data for a specific area.

Metric: A specific measurable variable used to gauge the change in a broader indicator (e.g., the metric "average crop yield per hectare, by crop type," may be used to measure the indicator "change in crop yield").

Monitoring: For this guidebook, *monitoring* refers to the process of collecting and analyzing information to measure progress on specific objectives that the restoration effort plans to achieve.

Open Foris Initiative: An initiative led by the Food and Agriculture Organization of the United Nations that supports the development and application of software and online tools for multipurpose forest inventories and data processing. The Open Foris suite of tools is a set of publicly available, open-source software to facilitate flexible and efficient data collection, analysis, and reporting for field and satellite data. Collect Earth and Collect Earth Online are part of the Open Foris suite of tools.

Raster Data: A matrix of cells or pixels that forms a grid, with each cell or pixel having an assigned value. Each cell or pixel can be georeferenced to a particular location on the ground. Satellite imagery and digital photographs are examples of raster data.

Remote Sensing: The remote sensing referred to in this guidebook is the collection of Earth observation data using satellites, aircraft, or other remote sources.

Sample Plot: The defined boundary of the area that will be assessed (i.e., sampled). In Collect Earth, the sample plot is the area inside the yellow box, and it can be customized to any dimensions.

Saiku: A web-based analytical tool that allows the user to aggregate data and create charts and graphs using a drag-and-drop interface. The tool is integrated into the desktop version of Collect Earth.

SEPAL (System for Earth Observations, Data Access, Processing & Analysis for Land Monitoring): A cloud-based computing platform that facilitates access to remote sensing data as well as the processing of that data. SEPAL is part of the Open Foris suite of tools developed by the Food and Agriculture Organization of the United Nations.

Survey Cards: In Collect Earth, survey cards are digital forms associated with each sample plot that contain the survey questions and are where the data collectors input their information when conducting the survey.

Trees Outside Forests: Trees that occur in cities, on farms, along roads, and within other land use/land cover types that are not, by definition, forest (FAO 2000).

EXECUTIVE SUMMARY

Forest and landscape restoration monitoring is an important component of a well-rounded restoration implementation strategy. This guide serves to assist stakeholders in monitoring tree-based restoration, with a focus on trees outside forests, such as trees on agricultural and pastoral landscapes and within cities and towns—using a Collect Earth mapathon approach.

HIGHLIGHTS

- Forest and landscape restoration monitoring is an important component of a well-rounded restoration implementation strategy. Assessing land use/land cover, tree cover, and other biophysical indicators over time provides critical information on whether the restoration intervention is effectively taking hold.
- Collect Earth is a data collection tool developed by the Open Foris initiative of the Food and Agriculture Organization of the United Nations, with which users can analyze high- and very-high-resolution satellite imagery to collect data on biophysical indicators such as land use/land cover, tree cover, and change over time.
- Collect Earth and the mapathon approach are especially useful for collecting data on "trees outside forests" (i.e., sparse tree cover on non-forest land uses, such as cropland) because they leverage very-high-resolution imagery and visual interpretation, which is typically more reliable for assessing sparse tree cover than other remote sensing methods.
- Planning, conducting, and processing the data from a Collect Earth mapathon involves eight key steps: developing a data use plan and influence strategy; defining the survey indicators and area of interest; designing the survey; designing the sampling scheme; organizing the mapathon; conducting the mapathon; assessing the data quality; and analyzing data and presenting results. The mapathon approach presents an opportunity to involve local stakeholders and people familiar with the landscape as data collectors and interpreters, which increases accuracy and creates a sense of ownership among end users of the findings and products produced.

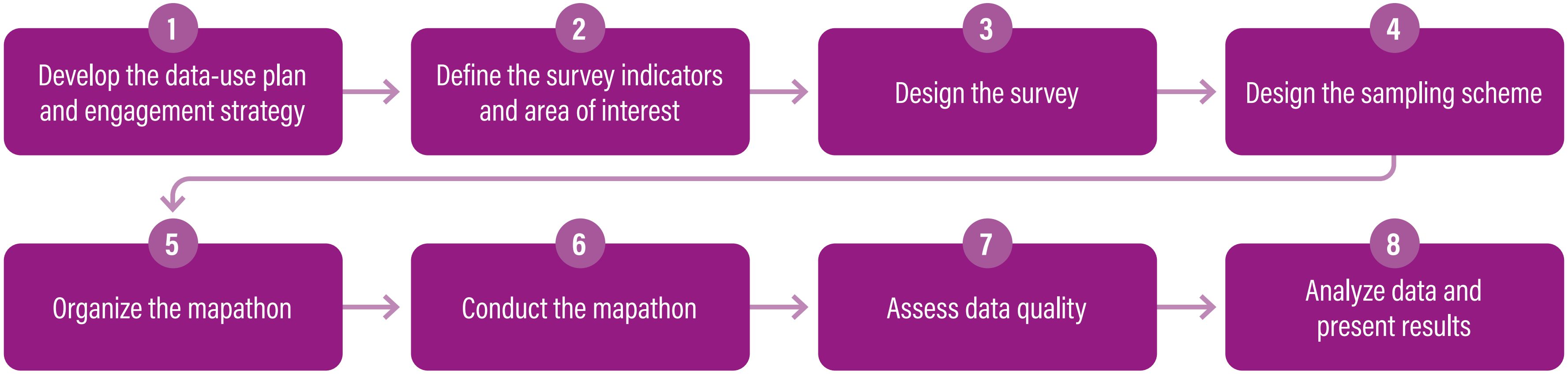
CONTEXT

Forest and landscape restoration is a process to regain ecological functionality and enhance human well-being across degraded landscapes (Lamb 2014; Chazdon et al. 2015; Besseau et al. 2018). Restoring degraded land generates numerous benefits for people, nature, and business, and dozens of national governments have made commitments to restoration as part of global and regional initiatives, including the New York Declaration on Forests, the Bonn Challenge, Initiative 20x20, AFR100, and ECCA30. An important next step is to monitor restoration activities to assess progress toward intended goals.

Since implementing a monitoring program for restoration can seem overwhelming at first, World Resources Institute (WRI) and the Food and Agriculture Organization of the United Nations (FAO) have initiated a series of publications that break down the process. Starting with *The Road to Restoration: A Guide to Identifying Priorities and Indicators for Monitoring Forest and Landscape Restoration* (Buckingham et al. 2019), WRI and FAO outline the steps to setting goals, choosing indicators, and defining metrics. This guide, *Monitoring Forest and Landscape Restoration Using Collect Earth Mapathons*, continues the series by providing guidance on collecting data for vegetation, land cover, and related indicators to support a restoration monitoring program using Collect Earth, a software tool developed by FAO's Open Foris initiative. Collect Earth enables users to analyze high- and very-high-resolution satellite imagery to monitor the state and change of land use/land cover and tree cover. It is especially useful for monitoring "trees outside forests" (i.e., sparse tree cover on non-forest land uses, such as cropland) because it leverages very-high-resolution imagery and visual interpretation, which is typically more reliable for assessing sparse tree cover than other remote sensing methods.

This guide provides an overview of how to implement Collect Earth "mapathons"—coordinated data-collection events that gather together a small group of practitioners to visually interpret imagery and complete surveys using Collect Earth. It walks the user through eight steps in the mapathon process, which cover the key components in how to plan, conduct, and process the data from a Collect Earth mapathon (Figure ES-1). Each of the steps in Figure ES-1 is the subject of a dedicated chapter and is illustrated using examples from four country case studies. Throughout the guide are a series of tips that highlight important lessons learned from the case studies or other recommendations based on the authors' experiences.

Figure ES-1 | Steps in Planning, Conducting, and Processing the Data from a Collect Earth Mapathon


1
Develop the data-use plan and engagement strategy
2
Define the survey indicators and area of interest
3
Design the survey
4
Design the sampling scheme
5
Organize the mapathon
6
Conduct the mapathon
7
Assess data quality
8
Analyze data and present results

Source: Authors.

WHO IS THIS GUIDE FOR?

This guide is intended for anyone who has established their goals for forest and landscape restoration and is examining ways to monitor progress toward those goals. It provides guidance on where to begin and what tools are available to support their monitoring program. This guide is not intended to serve as a manual on how to use Collect Earth; rather, it is meant to provide guidance on how to plan, organize, and conduct a mapathon to support biophysical data collection and further processing of the results for a restoration monitoring program. For resources on how to install and operate Collect Earth and other Open Foris software tools, visit openforis.org. Target audiences include restoration practitioners in government or civil society, land managers, land-use planners, researchers, and monitoring and evaluation professionals who are looking to integrate restoration data into their land use, disaster risk reduction, and watershed protection planning processes.

CASE STUDIES

This publication presents four case studies where WRI, FAO, and partners used Collect Earth mapathons to collect biophysical data on landscape features to assess various characteristics such as progress toward tree cover goals or identify opportunities to further implement landscape restoration activities. Summaries of the case studies are as follows:

- **Cerrón Grande watershed, El Salvador.** The government of El Salvador supported using a Collect Earth mapathon approach to collect data on recent changes in land use/land cover and tree cover and identify restoration opportunities in a critically important watershed that helps meet water demand from the capital city, San Salvador. The mapathon, conducted in 2016, developed a land use/land cover map, quantified changes in tree cover between 2000 and 2016, and estimated the number of trees outside forests.
- **Sodo Guragie Woreda, Ethiopia.** The Ethiopian Environment, Forest and Climate Change Commission used Collect Earth to develop a unique Tree Assessment Survey to monitor tree-based restoration progress at the *woreda* administrative level. The objective of the survey was to report on and inform the implementation of the national Climate Resilient Green Economy strategy and assess progress toward the woreda's target of 19 percent forest cover, which was set in the woreda's Growth and Transformation Plan. Data were collected

over the course of two six-day mapathons: In December 2017, 20 experts collected data for 2,410 plots for the target year 2010. In October 2018, 19 experts collected data for 2,452 plots for the target year 2015. Tree cover and distribution statistics for Sodo Guragie were produced for 50 indicators, including percent tree cover by land use/land cover, for the target years 2010 and 2015.

- **Sidhi District, India.** The Collect Earth mapathon for Sidhi was conducted in March 2017 as part of an assessment of tree-based landscape restoration opportunities in the district. The objective was three-fold: set a baseline of tree cover outside the forest; identify existing patterns of agroforestry and tree-based interventions; and identify areas with potential for increasing tree cover in the district. Additionally, details of land use, tree species, cropping patterns, and irrigation status were gathered. An important component of the mapathon was the participation of local people from Sidhi, which included farmers and youth who played a crucial role in identifying tree species and crop types. The local participants were paired with students and young professionals with prior knowledge of Collect Earth to help guide them through the process. The findings from the mapathon enabled estimations of the potential for landscape restoration in the district and identification of scalable restoration interventions.

- **Gatsibo District, Rwanda.** National and district stakeholders conducted a Collect Earth mapathon in 2016 to set a baseline for tree cover in the district and to assess progress toward meeting a target of 30 percent forest cover, which was identified in the district's development plan. It was especially useful for identifying which sectors (smaller administrative units within the district) were closer or farther from the target, to show where more investment in restoration activities was needed. The findings supported the district officials and stakeholders during the restoration planning and decision-making process.

  In this process, agroforestry and other trees outside forests were considered priorities in helping to mitigate the demographic pressure on the forest and landscape restoration initiatives, and to achieve specific United Nations Sustainable Development Goals.

Monitoring is an essential step in mobilizing stakeholders around a restoration vision in a landscape, as data and analyses show progress, highlight best practices, and provide information about locations needing improvement. Yet, monitoring is notoriously challenging to plan and implement due to the complexities of heterogeneous landscapes, the range of available tools and techniques, and the slow pace of tree growth. The process outlined in this guidebook, and the supporting examples from various case studies, demonstrates one option for assessing biophysical progress on restoration as part of a holistic monitoring framework.

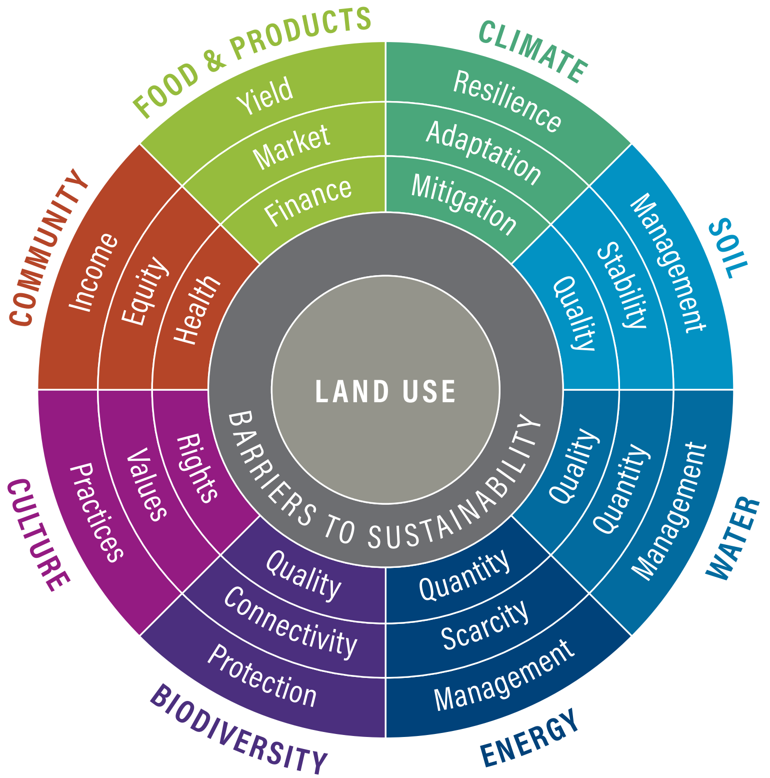
INTRODUCTION

This guide provides an overview of how to assess restoration progress using Collect Earth—a software tool developed by FAO to visually interpret satellite imagery to document the biophysical properties of the landscape that can be detected with the human eye—as one part of a holistic restoration monitoring framework. The guide is a follow-on to FAO and WRI's publication, *The Road to Restoration: A Guide to Identifying Priorities and Indicators for Monitoring Forest and Landscape Restoration* (Buckingham et al. 2019), which provides guidance on how to develop a monitoring framework based on prioritization of restoration objectives.

This guide, developed by World Resources Institute (WRI) and the Food and Agriculture Organization of the United Nations (FAO), serves to assist stakeholders in monitoring tree-based restoration, with a focus on trees outside forests, such as trees on agricultural and pastoral landscapes and within cities and towns. The guide is a follow-on to FAO and WRI's recent publication, *The Road to Restoration: A Guide to Identifying Priorities and Indicators for Monitoring Forest and Landscape Restoration* (Buckingham et al. 2019). *The Road to Restoration* supports users in setting up a monitoring framework by explaining how to define restoration goals and identify indicators of progress for restoration activities based on those restoration goals. This publication provides users with guidance on how to monitor biophysical progress on restoration, once indicators have been selected and a framework has been put in place. The guide focuses on how to monitor restoration using Collect Earth, a software tool developed by FAO to visually interpret satellite imagery to document the biophysical properties of the landscape that can be detected with the human eye. Collect Earth is part of FAO's publicly available, open-source suite of online tools called Open Foris, which supports data collection of metrics related to land use/land cover, tree cover, and their changes over time (See Box 1).

Collect Earth is typically used as part of coordinated data collection events called "mapathons," which involve a group of participants who visually interpret satellite imagery and complete surveys about biophysical aspects of the landscape in a particular area of study. The power of a mapathon is in the collective action. A group of participants can together collect thousands of data points in a relatively short amount of time (e.g., several days)—an accomplishment that would take an individual much longer to achieve (e.g., weeks or months). Participants in the mapathon, or data collectors, can have a wide range of backgrounds and may include university students, project managers in government agencies, agronomists, forest and land planning officers, local community members, and many others. Commonly, they are national or local stakeholders who are familiar with the landscape to be assessed during the mapathon. This guide focuses on using Collect Earth mapathons as a part of a participatory monitoring program and therefore urges users to conduct their activities in the cultural, social, and political contexts of the country or region where the mapathon will be implemented. The overall objective of this guide is to inform users on how to conduct a Collect Earth mapathon to measure biophysical progress on forest and landscape restoration as part of a holistic monitoring framework. Throughout the guide, examples from four country case studies—in El Salvador, Ethiopia, India, and Rwanda—are used to highlight key components of the mapathon process. These case studies were selected because they represent a variety of contexts in which Collect Earth can be used to monitor restoration with respect to geographic location, objective for data collection, and target audience for communicating results.

Figure 1 | The Restoration Goal Wheel


FOOD & PRODUCTS
Yield
Market
Finance
CLIMATE
Resilience
Adaptation
Mitigation
SOIL
Management
Stability
Quality
WATER
Management
Quantity
Quality
ENERGY
Management
Scarcity
Quantity
BIODIVERSITY
Protection
Connectivity
Quality
CULTURE
Practices
Values
Rights
COMMUNITY
Income
Equity
Health
LAND USE
BARRIERS TO SUSTAINABILITY

Source: Buckingham et al. 2019.

Before embarking on a Collect Earth mapathon, it is important to consider how it fits into a larger framework for monitoring forest and landscape restoration. This means understanding the goals for restoration and the changes you expect to see in the landscape as a result of restoration activities. If you have not yet developed a monitoring framework, we suggest referring to the publication *The Road to Restoration: A Guide to Identifying Priorities and Indicators for Restoration Monitoring*, which features a step-by-step process for selecting and prioritizing among eight common restoration goal-themes and choosing appropriate indicators and metrics based on selected goal-themes (Buckingham et al. 2019). The restoration goal wheel (Figure 1) displays the goal-themes and examples of related subthemes. The publication walks users through seven questions considering the goals and targets for restoration, including the proposed land-use interventions.

Once you've answered those questions, this Collect Earth guidebook can support users in deciding how to use Collect Earth to measure progress on the effects of land use interventions and other biophysical indicators identified in the monitoring framework, such as the state and change of land use/land cover, tree count, and tree cover.

1.1. RESTORATION MONITORING USING COLLECT EARTH

This guide focuses on conducting assessments of the biophysical conditions that result from forest and landscape restoration activities. Assessing the physical changes in land use/land cover as well as tree cover and distribution over time provides indicators of whether the restoration intervention is effectively taking hold. Even if the restoration intervention is successful, it does not mean that other initiatives such as the ones focused on socioeconomic progress are successful. These other approaches have to be measured, assessed, or estimated by different criteria, methods, and tools. For more information on how to measure progress on socioeconomic indicators, see *The Road to Restoration: A Guide to Identifying Priorities and Indicators for Restoration Monitoring* (Buckingham et al. 2019).

Box 1 | What Is Collect Earth and the Open Foris Suite of Tools?

Open Foris is an initiative led by the Food and Agriculture Organization of the United Nations (FAO) that supports the development and application of software and online tools for multipurpose forest inventories and data processing/analytics. The Open Foris suite of tools is a set of publicly available, open-source software to facilitate flexible and efficient data collection, analysis, and reporting for field and satellite data. Collect Earth is a data collection tool that is part of the Open Foris suite, where users can analyze high- and very-high-resolution satellite imagery in combination with other available remotely sensed data to monitor the state and change of land use/land (Bey et al. 2016). Built on Google Earth Pro and Google Earth Engine cloud computing technologies, Collect Earth facilitates access to multiple publicly available archives of satellite imagery, including archives with very high spatial and temporal resolution imagery (e.g., DigitalGlobe, Spot 5 and 6, Landsat, Sentinel-2) via Google Earth, Bing Maps, and Google Earth Engine (Bey et al. 2016). Collect Earth can be used for many purposes, including monitoring forest and landscape restoration; providing data for REDD+ Measuring, Reporting and Verification (MRV) systems; conducting national forest inventories, disaster assessments, and humanitarian work; and more. Users can configure the data collection form, sampling design, plot size, temporal range, and scale to match each purpose (Bey et al. 2016). For example, in 2017, Collect Earth was used via a series of mapathons conducted around the world to assess the extent of forest area in the world's drylands—a biome that has been historically underrepresented in forest cover estimates—which led to a 9 percent increase in the estimate of global forest cover (Bastin et al. 2017).

Collect Earth Online, launched in December 2018, is a web-based version of Collect Earth that performs all data collection and management functions online, eliminating the need for desktop software installation (Saah et al. 2019). This tool is well suited for simple land use/land cover change assessments and crowd-sourcing data collection activities from a large pool of users, given that data are stored online within the project and not on individuals' computers (Saah et al. 2019).

The Open Foris suite includes several other software tools, summarized in Table B1.1. The Open Foris website provides links to download the different tools, as well as tutorials to guide users through the installation and utilization of the software. It hosts an active Community Support section where users can ask questions and make requests.

TOOL	FUNCTION
Collect Earth	To collect data on the state and change of land use/land cover using high- and very-high-resolution satellite imagery; this desktop-based tool is integrated into a Google Earth interface
Collect Earth Online	A web-based version of the Collect Earth desktop-based tool where all data are collected and managed in the cloud
Collect	To design and customize the data collection survey for the desktop version of Collect Earth
Collect Mobile	To collect data from the field via an Android app
Calc	To analyze data and calculate results
SEPAL (System for Earth Observations, Data Access, Processing & Analysis for Land Monitoring)	To access and process satellite data repositories hosted within Google Earth Engine and produced by the National Aeronautics and Space Administration and the European Space Agency (among others)
Saiku	To aggregate and analyze data and produce graphical interpretations; a customized version of the software is integrated into the installation package of Collect Earth

Source: Open Foris.

1.1.1. HOW IS LAND USE/LAND COVER CHANGE MONITORED?

Earth observation satellites have been used since the 1960s to monitor land use/land cover changes (Jensen 1996). Satellite-based remote sensing includes both the technologies used to observe Earth from space (e.g., platforms, data transmission, and storage devices) and the methodology (e.g., image analyses) used to extract information. Today, hundreds of Earth observation satellites are in orbit, delivering remotely sensed data ranging from optical to radar data and from multispectral to panchromatic imagery, and covering various spatial and temporal resolutions. Satellite remote sensing can be efficient and cost-effective for land use/land cover monitoring since satellite platforms can deliver timely, replicable, and consistent data from the local to national levels (Wang et al. 2010).

In this document, we differentiate between two types of monitoring of land use/land cover and change:

Algorithm-based classification: This method uses the spectral and textural analysis of satellite imagery in combination with statistical classifiers, such as machine learning algorithms. Classifiers interpret the signature of vegetation and land use changes and categorize them according to the type of change. Image classification approaches include the following:

1. Unsupervised algorithms in which a map is generated by clustering pixels of similar spectral properties

2. Supervised algorithms in which the spectral signatures of selected image pixels are used as training samples in a classification algorithm and, through interpolation and extrapolation, to estimate the values of the remaining pixels and assign class labels accordingly

3. Object-based classification in which pixels are grouped into representative shapes and sizes and assigned different class labels (Weih and Riggan 2010)

There are advantages to being able to classify many pixels in a short amount of time through computer automation, which makes this method more suitable for classifying large areas. However, the resulting maps will contain errors, which must be assessed and reported to understand and communicate the results accurately. For example, it has been documented that many classifiers do not predict percent tree cover well in regions where the percentage of trees per pixel is low compared with regions with high canopy coverage. This is because the spectral signature of the canopy is mixed with other land covers present in the pixel.

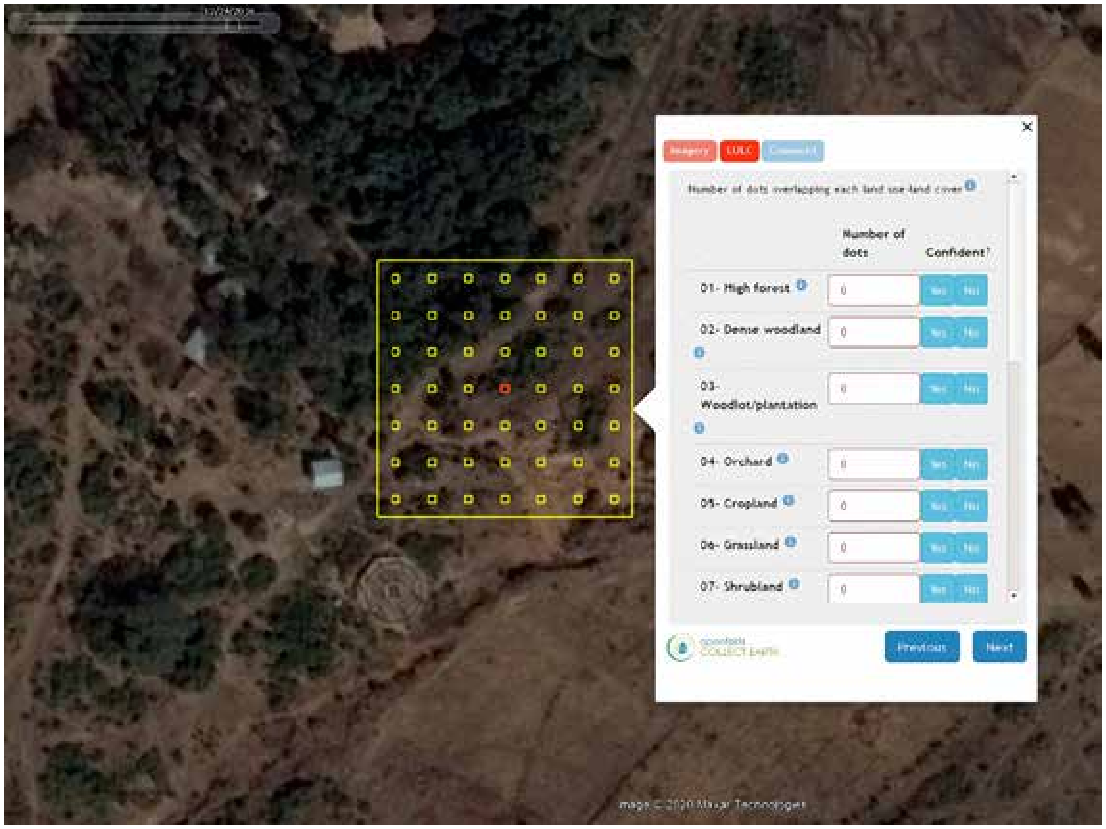
Visual interpretation: This method involves a person visually interpreting very-high-resolution (<50 centimeters) imagery to classify various aspects of vegetation and land use/land cover change. Its comparative advantage to algorithm-based classification is that it is typically easier for the human eye to detect subtle variations in land use/land cover, and the nuances can be recorded more accurately. This method is especially advantageous in highly heterogeneous landscapes where there is a wide variety of vegetation and mixed land use/land cover types. It is often difficult to train an algorithm to detect such subtle variations and changes over time. Another benefit is that it does not require a remote sensing specialist to interpret the imagery, and so there is greater opportunity to involve local people who are familiar with the landscape as interpreters and capitalize on local knowledge (Bey et al. 2016). Local people can detect features specific to their landscape that the automated method may not capture with the same accuracy. Human interpretation of imagery by inexperienced interpreters can also lead to errors and uncertainties in the assessment or estimation of feature coverage, especially when many interpreters are involved. However, the interpretation made by local people along with advance training on how to interpret imagery and best practices can help reduce human errors and characterize limitations.

1.1.2. HOW CAN COLLECT EARTH BE USED TO MONITOR LAND USE/LAND COVER CHANGE?

Collect Earth is a sample-based tool where data are collected via survey questions for a series of sample plots that are overlaid with satellite imagery (Figure 2). Collect Earth leverages human interpretation and classification of very-high-resolution satellite imagery. The premise is that the human eye can more easily detect complex land cover types, such as agroforestry systems (i.e., trees intermixed with cropland) that are difficult for automated algorithms to identify consistently. As shown in Figure 2, within each sample plot (larger yellow box) are rows of control points (smaller yellow boxes/dots) that are spaced at equal intervals. These control points help the data collector estimate the percent coverage of the plot by a certain land use/land cover type or tree cover.

The same survey questions are answered for each plot, and the collected data are aggregated into a geo-referenced database. The survey questions may ask about type of vegetation and percent coverage, types of infrastructure that are visible, the percent of tree cover within the plot, and other features. The results can provide valuable statistics about the land use/land cover properties of the surveyed landscape, and if data are collected for the same sample plots for multiple points in time, then changes in biophysical properties can be assessed. Each aspect of the Collect Earth survey—the survey questions, sample plots (i.e., number of plots, size, spacing)—is customizable by the survey designer to match the objectives of the monitoring effort, as shown in Steps 3 and 4.

Figure 2 | Example of Collect Earth Survey Card, Sample Plot, and Control Points



Number of dots overlapping each land use land cover

	Number of dots	Confident?
01- High forest	0	Yes No
02- Dense woodland	0	Yes No
03- Woodlot/plantation	0	Yes No
04- Orchard	0	Yes No
05- Cropland	0	Yes No
06- Grassland	0	Yes No
07- Shrubland	0	Yes No

Note: Within each sample plot (larger yellow box) are rows of control points (smaller yellow boxes/dots) that are spaced at equal intervals. These control points help the data collector estimate the percent coverage of the plot by a certain land use/land cover type or tree cover.
Source: Obtained from Collect Earth and Google Earth.

CHAPTER 1:

EIGHT STEPS FOR IMPLEMENTING A COLLECT EARTH MAPATHON

Planning, conducting, and processing the data from a Collect Earth mapathon involves eight key steps: developing a data use plan and influence strategy; defining the survey indicators and area of interest; designing the survey; designing the sampling scheme; organizing the mapathon; conducting the mapathon; assessing the data quality; and analyzing data and presenting results. The steps were derived from the authors' collective experiences in conducting mapathons in four countries—El Salvador, Ethiopia, India, and Rwanda.

2.1. DEVELOPMENT OF THE EIGHT-STEP PROCESS

While restoration monitoring programs are highly specific to the goals of forest and landscape restoration and the area of interest, there are several overarching steps to follow to ensure that the data collection effort is well-developed to support the monitoring goals. These eight steps are outlined in Figure 3 and are discussed in detail in the following chapters. The steps were derived from the authors' collective experiences in conducting pilot mapathons in four countries—El Salvador, Ethiopia, India, and Rwanda—between 2016 and 2018. The authors of this guidebook were involved in the implementation of the mapathons for the case studies featured in this publication. After comparing the processes and lessons learned across these case studies, the authors determined that there is a fundamental set of activities and a sequence in which to conduct mapathons that is best for monitoring restoration efforts using Collect Earth. To develop the steps that are illustrated in Figure 3, the tasks associated with each case study were listed, compared, and consolidated into buckets of key sets of activities. These steps represent a newly derived framework that we recommend for projects that intend to monitor restoration activities using Collect Earth.

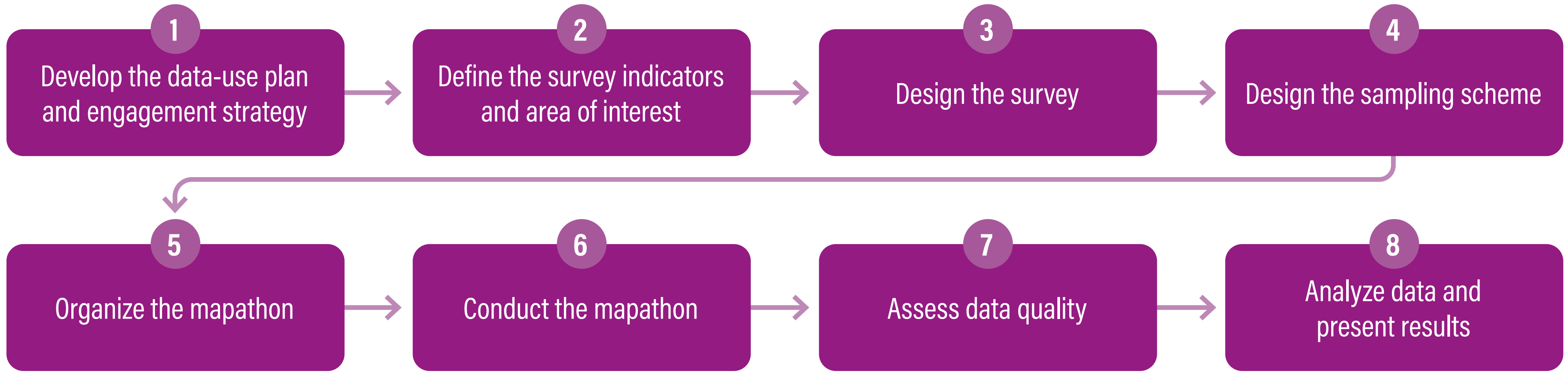
Given that the steps were developed after the case study mapathons had ended, activities associated with each step varied to some degree in each case study application. Throughout this guide, examples from case studies are used to illustrate the steps where there was the most relevant information or lessons learned to share.

2.2. OVERVIEW OF THE EIGHT-STEP PROCESS

The majority of the steps (Steps 1 to 5) comprise a "pre-mapathon" preparation and planning phase. Based on the authors' experiences, the pre-mapathon preparation is the most crucial for ensuring mapathon success, yet also the portion that is most likely to be compressed due to short timelines or an urgency to obtain results. Step 1 (developing the data use plan and engagement strategy) provides guidance on thinking through how the data will be used by the target audience, which then influences which types of data are collected (Step 2) and how the survey is designed (Steps 3 and 4). Dedicating ample time to Step 1 ensures that the most relevant and useful data are collected, which reduces the risk of having to backtrack later on to add more indicators or spending valuable time collecting irrelevant information.

Steps 5 and 6 focus on the mapathon event itself, both organizing it and conducting it. The case study mapathons (or pilot applications) helped to fine-tune the process for identifying good practices and making recommendations for the "who, what, when, and where" of organizing and

Figure 3 | Steps in Planning, Conducting, and Processing the Data from a Collect Earth Mapathon


1
Develop the data-use plan and engagement strategy
2
Define the survey indicators and area of interest
3
Design the survey
4
Design the sampling scheme
5
Organize the mapathon
6
Conduct the mapathon
7
Assess data quality
8
Analyze data and present results

Source: Authors.

conducting the mapathon event, including the types of participants to invite, what equipment and training is needed, how much time should be dedicated, and what types of facilities are best-positioned to host the event.

Steps 7 and 8 represent the post-mapathon phase, which includes assessing data quality and presenting results. The execution of Step 7 (assessing data quality), in particular, varied across the pilot applications. While all case studies included an assessment of the collected data to rectify anomalies and inconsistencies, only two of the four cases, Rwanda and India, conducted groundtruthing. This extra step was found to be highly valuable for improving confidence in results, both for the data collectors and target audiences. Step 8 (analyzing data and presenting results) represents the crux of the mapathon and most important step for translating the data into actionable information; therefore, examples of data and communication products were included from all four case studies.

Background information on each case study is provided in Table 1.

Table 1 | Overview of Mapathons in Four Case Study Countries: El Salvador, Ethiopia, India, and Rwanda

	EL SALVADOR	ETHIOPIA	INDIA	RWANDA
Landscape assessed	Cerrón Grande watershed	Sodo Guragie Woreda	Sidhi District, Madhya Pradesh State	Gatsibo District
Stakeholder objective for mapathon	Set a baseline for tree cover outside forests to inform restoration planning for a strategic water catchment area that helps meet water demand from the capital city, San Salvador	Monitor change in tree cover and distribution over the first five years of Ethiopia's development blueprint, the Climate Resilient Green Economy strategy, to report on progress and inform implementation for the next five years	Understand existing tree cover outside forests and tree-based restoration interventions in Sidhi to identify opportunity areas for additional interventions	Set a baseline for tree cover outside forests to inform district-level restoration planning
Outputs generated	Baseline statistics on tree cover and tree density and land use/land cover map	Statistics on tree cover and distribution change from 2010 to 2015 for trees inside and outside the forest	Baseline statistics on tree cover outside the forest; inventory of existing tree-based interventions on farmland	Baseline statistics on tree cover
Area of landscape	110,000 ha	95,000 ha	378,444 ha	157,800 ha
Length of mapathon	4 days: - 0.5 days training - 3 days data collection - 0.5 days presenting results	5 days for 2010 and for 2015 each: - 1.5 days training - 2.5 days data collection - 1 day controlling quality	5 days: - 5 days data collection (data collectors had been trained previously)	5 days: - 1.5 days training - 3.5 days data collection
Cost of mapathon	$4,000: Included 23 data collectors and travel fees for 4 out-of-country observers	$8–10,000: Included compensation, travel fees, and event venue for 20 data collectors	$25–30,000: Included 20 data collectors housed overnight	$5,000: Included 20 data collectors, travel fees
Data collectors for the mapathon	Government officials, officials from city and the landscape, and observers from Honduras	Regional and district experts, NGOs, university lecturers	GIS students and young professionals familiar with Collect Earth and farmers, youth, and other stakeholders from Sidhi	Government agronomists, GIS teachers, GIS students, NGOs

Table 1 | Overview of Mapathons in Four Case Study Countries: El Salvador, Ethiopia, India, and Rwanda, continued

	EL SALVADOR	ETHIOPIA	INDIA	RWANDA
Target audiences for data produced by the mapathon	Minister of environment, the ministry's staff, and the public	Federal, regional, zonal, and district administrations for Environment and Forests, Agriculture, Water, Finance and Economic Cooperation	State and district government, National Bank for Agriculture and Rural Development (NABARD), NGOs working on restoration, and the private sector	Rwanda Water and Forestry Authority, district leadership, and forest officers
Key indicators of interest	1. Tree cover 2. Tree density 3. Land use/land cover change between 2011 and 2016	1. Percent area of 13 land use/land cover classes 2. Percent tree cover in each land use/land cover class and total, in gullies, and on treated land 3. Spatial pattern of trees (clustered, scattered, linear patterns, regular) in cropland, grassland, rural compound, and settlement 4. Percent linear features (waterbody, roads, bunds/terraces, gully banks, boundaries) with tree canopy	1. Land use/land cover change 2. Tree cover 3. Tree count 4. Existing tree-based restoration interventions in farmlands and associated tree species	1. Tree cover 2. Tree density 3. Land use/land cover
Land-use focus	Forests and trees outside forests	Trees in all land use/land cover classes, along key linear features, on treated land and in gullies	Forest, cropland, and other areas	Trees outside forests, specifically on cropland, grassland, wetland, settlement, and some types of shrubland

Note: A *woreda* is an administrative level in Ethiopia. Ha stands for hectares; NGO for nongovernmental organization; GIS for geographic information system.

Source: Authors.

CHAPTER 2:

STEP 1: DEVELOP A DATA USE PLAN AND ENGAGEMENT STRATEGY

The first step in preparing for a Collect Earth mapathon is determining what data need to be collected and how they should be presented to best serve the needs of key stakeholders. A data use plan and engagement strategy will help you to define the data collection needs by thinking backward from the perspective of the end users of the data.

Before collecting any data, consider who the prospective end users of the data will be and the format that would be most useful for presenting the data. A data use plan and engagement strategy describe your larger data use goals and target audience. Specifying the end users and their information needs at the project onset helps to define the scope of data that should be collected.

3.1. DEVELOP A DATA USE PLAN

The first step before beginning a Collect Earth mapathon is discussing and deciding what data will be collected. The sample plan in Table 2 outlines several key questions that will help guide what data to collect as part of the mapathon. The questions in this sample plan were derived from the authors' collective experiences planning mapathons in various countries and represent the most important questions to ask at the start of the process. These questions will help align data collection efforts with the stakeholders' objectives and expectations (see Case Study Highlights 1 and 2). It is important to develop a data use plan with input from the principal stakeholders and dedicate ample time to determining what data to collect. Once the data collection process begins, it is difficult to change the plan or include additional data.

Table 2 | A Sample Data Use Plan

1. Who is your target audience for the data and results of the Collect Earth mapathon? How do you expect your target audience to use the data that you collect?
2. What defined or mandated output, plan, or strategy would data from the Collect Earth mapathon help achieve?
3. What outcomes will illustrate that the Collect Earth mapathon has been successful?
4. Are there any monitoring programs already in place or similar monitoring tools already being used? If so, how will you ensure that the data complement existing monitoring activities?
5. How will you communicate the results and/or share collected data with your target audience?

Source: Authors.

3.2. DEVELOP AN ENGAGEMENT STRATEGY

The data use plan will help shape the survey by specifying the kinds of data that stakeholders will need to better inform their decisions. The next step is to consider how the collected data and results should be presented and/or shared based on the data use plan. You'll want to focus on who your target audience is, how they will want to receive the information, and what actions or decisions they are considering. While the specifics will depend on the findings of the data collection and analysis effort, identifying your target audience and their needs early will help streamline the process for analyzing and presenting the data at a later stage.

The more specific you are in the data use plan, the closer you will be to reaching your target audience and providing results in a format that speaks to their needs. For example, in identifying the target audience who will benefit from this work (question 1 in the sample data use plan), we recommend specifying both the organizations and the positions of those audience members. You may also want to establish levels of priority among your target audience members depending on your data use objectives to help prioritize the development of communications products after you've completed the data collection and analysis phase.

After specifying the target audience for your data, consider what reporting format will best suit their needs, noting that it may be different depending on the audience member. For

example, a university professor may want to use the raw data from Collect Earth to conduct research, while a restoration practitioner may be interested only in the collective results and implications for restoration planning.

Involve your partners and stakeholders in the planning process as much as possible to shape how to share data and communicate the results to each type of audience. See Case Study Highlights 1 and 2 for examples of how data use plans and engagement strategies were developed for the case studies in Rwanda and Ethiopia.

The following questions can help guide how to develop the engagement strategy. The questions are framed in terms of "channel" (i.e., a platform for communication) and "format" (i.e., how the data are presented), with several example options for each:

CHANNEL: *How do you expect to reach your target audience and encourage action?*

1. International conferences
2. National workshops
3. One-on-one meetings
4. Local media article
5. Social media
6. Series of discussions among technicians (i.e., working groups or task force)

FORMAT: *What presentation format best communicates the results to your audience?*

1. Executive or one-page summary with key graphs and statistics
2. Publication or report
3. Article in an academic journal
4. PowerPoint presentation with key graphs and statistics
5. In-person explanation via formal or informal small group meetings
6. Infographics

Tip: Involve Decision-Makers Early and Often

Reach out to local, regional, or national decision-makers early in the planning stages of your mapathon. Getting their support for the data collection can facilitate mapathon preparation by improving coordination or logistics or making it easier to find interested data collectors. Also, co-developing the mapathon process with decision-makers will build trust and facilitate co-ownership of the findings, thereby creating an environment where the monitoring results can more quickly be adopted to inform and improve action and implementation. In some cases, you may want to design all stages of the mapathon collection process—the survey cards, sample plots, and area of interest—with the decision-makers.

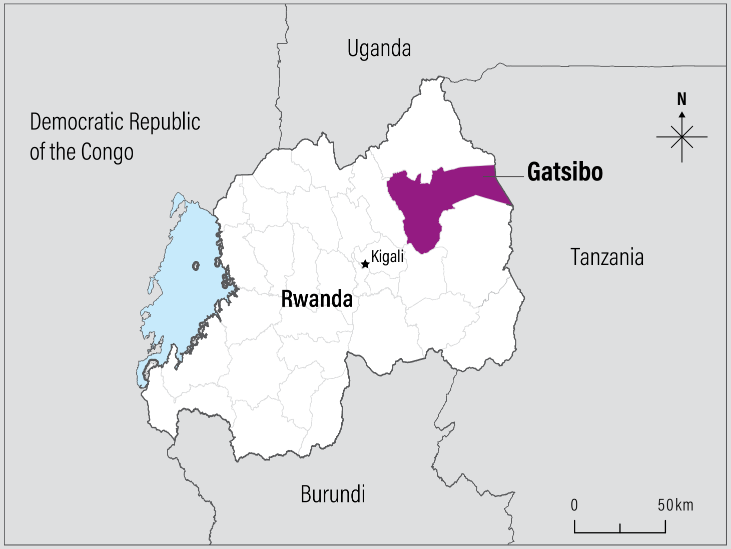
CASE STUDY HIGHLIGHT 1.

Designing the Data Use Plan for the Collect Earth Mapathon in Rwanda’s Gatsibo District

Gatsibo District is located in the Eastern Province of Rwanda where 85 percent of the population depends on crop production and livestock farming but a dry climate makes farming a challenge (Figure 4; NISR 2015). As a result, restoration activities need to align with district priorities for agriculture, as outlined in six sustainable landscape management plans spanning 55 sites. The national and district stakeholders wanted to conduct a Collect Earth mapathon to understand the current tree cover conditions for these areas. District leaders were also interested in learning how close they were to achieving the district development target of 30 percent forest cover by 2020.

The data use plan that was developed for Gatsibo District identifies how the data can be used to guide outreach activities following the mapathon (Table 3).

Figure 4 | Location of the Case Study: Gatsibo District, Rwanda



Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Source: Map produced at WRI using data from MINITRACO and NUR-CGIS (2005).

Table 3 | Data Use Plan Developed for Gatsibo District, Rwanda

1. Who is your target audience for the data and results of the Collect Earth mapathon? How do you expect your target audience to use the data that you collect?

The target audience for the data and results of the Collect Earth mapathon are district leaders (e.g., mayors, vice mayors, and district forest officers); restoration technicians; and nongovernmental organizations working in Gatsibo District. These groups often collaborate to plant trees, provide guidance on land management, and monitor progress on restoration activities in the field in support of the national and district mandate to increase forest cover to 30 percent by 2020. Each of these groups will use the data on tree cover to make plans and set priorities for restoration activities to achieve the forest cover target.

2. What defined or mandated output, plan, or strategy would data from the Collect Earth mapathon help achieve?

Rwanda's national Vision 2020 set a goal of 30 percent forest cover by 2020, and the national agroforestry plan mandates increased tree cover in agriculture areas, such as through adoption of agroforestry systems. The Collect Earth data would support reporting progress on this goal.

3. What outcomes will illustrate that the Collect Earth mapathon has been successful?

- Collect Earth data and derivative metrics are used in the annual Imihigo reports, which evaluate Gatsibo's performance against the District Development Plan.
- Data are used as an input to strategic planning efforts and when drafting the new District Development Plan for 2019–2023.
- Nongovernmental organizations working in the district use the data and metrics to demonstrate progress and/or set priorities when coordinating new projects.

4. Are there any monitoring programs already in place or similar monitoring tools already being used? If so, how will you ensure that the data complement the existing monitoring activities?

Yes, there are current monitoring programs in place that use paper-based worksheets to collect forest cover and land use data, including methods for how to calculate composite indicators. The main challenge across districts is the lack of staff available to complete worksheets. Transitioning this data collection process to Collect Earth will create a more repeatable and less work-intensive process. The process will also complement ongoing efforts to establish a new National Forest Monitoring and Evaluation System. The team joined the National Forest Monitoring Task Force to ensure that data would contribute to ongoing national and district discussions on development of this system.

5. How will you communicate the results and/or share collected data with your target audience?

Outreach strategies were tailored to the specific audience:

- District leadership: Coordinated one-on-one meetings to share key statistics and talking points and a one-page fact sheet to empower district leadership to use data to inform district plans and shape the direction of restoration projects in the district.
- Restoration technicians, district monitoring and evaluation officers, and nongovernmental organizations: Presented key statistics and graphs, a one-page fact sheet, and an explanation of how the information matters to them with clear recommendations on how they could use the insights to improve operations and be ambassadors for sustainable forestry and agroforestry.

Source: Authors.

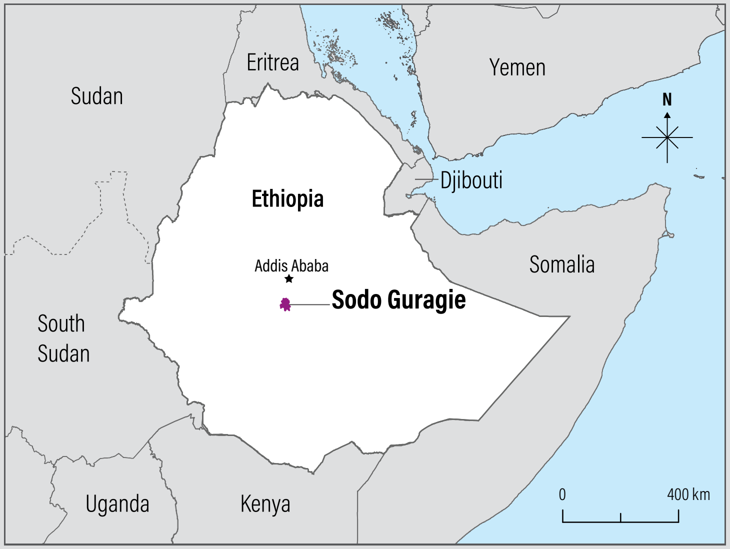
CASE STUDY HIGHLIGHT 2.

Designing the Data Use Plan for the Collect Earth Mapathon in Sodo Guragie, Ethiopia

Ethiopia prioritized implementing tree-based landscape restoration interventions to support its economic, social, and environmental goals. To help assess progress on their efforts, the Ethiopian Environment, Forest and Climate Change Commission led the development of a monitoring system for tree-based landscape restoration with the support of WRI and a team of national, regional, zonal, and district experts.

The monitoring system is composed of a Tree Assessment Survey that uses Collect Earth and a mapathon approach. Biophysical indicators related to tree cover and distribution inside and outside the forest were assessed during the mapathon. The strategy was piloted at the *woreda* administrative level: in Sodo Guragie, located just south of the country's capital of Addis Ababa in the Southern Nations, Nationalities, and Peoples' Region (Figure 5), and in Meket in Amhara Regional State. For Sodo Guragie, as part of the planning process for the mapathon, the following data use plan helped define the objectives and target audience (Table 4).

Figure 5 | Location of the Case Study in Sodo Guragie, Ethiopia



Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.
Source: Map produced at WRI using data from Central Statistical Agency (2007).

Table 4 | Data Use Plan Developed for Sodo Guragie, Ethiopia

1. Who is your target audience for the data and results from the Collect Earth mapathon? How do you expect your target audience will use the data that you collect?
The local administration of Sodo Guragie is the primary target audience. The Collect Earth data will help report on the rehabilitation of degraded land, watershed development, and forest cover. It will also help inform district planning by identifying opportunities for specific interventions in specific *kebeles* (the smallest administrative unit in Ethiopia), such as promoting the use of trees along bunds and terraces, or on communal pasture lands.
2. What defined or mandated output, plan, or strategy would the data from the Collect Earth mapathon help achieve?
Monitoring tree-based landscape restoration in Ethiopia seeks to inform the Climate Resilient Green Economy (CRGE) five-year Growth and Transformation Plans (GTPs). These plans align national, regional, and local planning processes. The current GTP targets the rehabilitation of 22.5 million hectares of degraded land and improved watershed development for 41.35 million hectares, and aims to reach 20 percent forest cover by 2020. These targets are rolled down all the way to the district level. Districts report on their progress, which is then aggregated in reports at higher administrative levels up to the national level.
3. What outcomes will illustrate that the Collect Earth mapathon has been successful?
■ The collected data provide a comprehensive picture of tree cover and distribution in the woreda and are included in reports on progress toward the GTP targets. ■ The collected data support the assessment of trends in tree cover and distribution and inform the implementation of future tree-based interventions.
4. Are there any monitoring programs already in place or similar monitoring tools already being used? If so, how will you ensure that the data complement existing monitoring activities?
Current monitoring efforts (i.e., the National Forest Cover and Change Mapping, and the National Forest Inventory) focus on forests, defined as "trees, plants and other biodiversity accumulation at and in the surrounding of forest lands, roadsides, riverside, farm and grazing lands as well as residential areas or parks that grow naturally or developed in some other ways" (FDRE 2018). These monitoring efforts do not collect information on trees outside forests. A few indicators related to forests (e.g., high forest and dense woodland area, percent tree cover in high forest and dense woodland) were kept in the Tree Assessment Survey to have an independent assessment for forest extent and tree cover.
5. How will you communicate the results and/or share collected data with your target audience?
The results from the mapathons are compiled in a report. Local experts, many of whom are involved in the process and highly interested in the outputs of the assessment, will use the report for their reporting and planning as needed. In addition, the produced reports will serve as templates for future assessments, and will be used to increase awareness of and support for monitoring trees inside and outside forests with comparable information in different time series.

CHAPTER 3:

STEP 2: DEFINE THE SURVEY INDICATORS AND AREA OF INTEREST

It is important to identify Collect Earth survey indicators that reflect the goals for restoration and the changes you expect to see in the landscape as a result of restoration activities. When defining the area of interest, it is important to consider the size of the area, which will dictate the level of effort for collecting data, as well as the scale at which any restoration planning or decision-making processes occur that the data seek to inform.

The Collect Earth survey indicators need to closely align with the goals for restoration and the changes expected to occur in the landscape as a result of restoration activities. The process for defining the indicators is simpler when these components are already identified in a restoration monitoring framework. If you have not yet developed a monitoring framework, we suggest referring to the publication *The Road to Restoration: A Guide to Identifying Priorities and Indicators for Restoration Monitoring*, which features a step-by-step process for selecting and prioritizing among eight common restoration goal-themes and choosing appropriate indicators and metrics based on selected goal-themes (Buckingham et al. 2019).

The restoration monitoring wheel in Figure 2 displays common goal-themes and related subthemes. The publication walks users through seven questions considering the goals and targets for restoration, including the proposed land-use interventions. Once these questions have been answered, this Collect Earth guidebook can support users in deciding how to measure progress on land use interventions and measuring biophysical indicators identified in the monitoring framework, such as land use/land cover, tree count, and tree cover.

4.1. IDENTIFY THE INDICATORS FOR THE MAPATHON DATA COLLECTION

The indicators selected for the Collect Earth mapathon should focus on what can be seen and inferred with the human eye through satellite imagery, such as land use/land cover type, tree cover, and infrastructure. Think about how data can support reporting on existing national and subnational restoration targets and metrics. For example, tree cover alone may not provide useful information, but tree cover on cropland would indicate progress toward a national target on land under agroforestry. Table 5 lists examples of indicators that could be collected in a Collect Earth survey. See Case Study Highlights 3 and 4 for examples of how the indicators were selected for the case studies in Ethiopia and India.

Tip: Allocate Ample Time to Identify the Indicators to Be Collected

Identifying the data to be collected in the mapathon is a big task that requires multiple steps, from a desk review of national and subnational restoration targets to consultations with key stakeholders. We suggest first understanding how the proposed metrics apply to restoration targets in the area of interest, and then clearly pinpointing the value-add and limitations of these metrics to stakeholders.

Table 5 | Examples of Indicators and Metrics That Can Be Measured Using Collect Earth Mapathons

CATEGORY OF INDICATOR	METRIC
Land use/land cover	▪ Type of land use/land cover (e.g., forest, cropland, grassland, shrubland, settlement, bare land) ▪ Percent of each type of forest cover (e.g., plantation/woodlot, mangrove, natural forest, other forest)
Tree cover or count	▪ Percent tree cover ▪ Percent tree cover along waterbody banks, boundaries, bunds/terraces, roadsides, gully banks ▪ Number of trees per hectare
Tree spatial pattern	▪ Proportion of trees in cropland, grassland, rural compound, and settlement that are clustered, scattered, linear, or regular ▪ Agroforestry patterns for trees on bunds, trees on boundaries, and trees in home gardens
Qualitative survey questions	▪ Potential for increasing tree cover ▪ Species of trees ▪ Signs of irrigation ▪ Signs of forest stress ▪ Disturbances leading to change in land use and change in tree species

Source: Authors.

As shown in Table 5, Collect Earth is most commonly used to collect data on trees, particularly for restoration monitoring, although any landform detectable on very-high-resolution satellite imagery can be monitored.

4.2. DEFINE THE AREA OF INTEREST (LANDSCAPE)

The size of the area to be assessed will affect how you customize the sample design for data collection. Understanding how restoration activities are coordinated can help you define your area of interest. For example, if activities are funded and implemented at the district level, then collecting data at that scale can support priority-setting.

Tip: Consider Excluding Irrelevant Land Use/Land Cover Types from Your Area of Interest

If choosing an administrative area like a district, you may want to decide with stakeholders which land uses within the district should be included. This will help narrow down the size of the data collection area and help you avoid spending time on areas that are not relevant to the goals of the exercise. For example, if agroforestry is the only type of restoration to be monitored, then it would be important to include croplands and discuss excluding other land-use types such as urban areas, forests, and water bodies. While it is beneficial to narrow the scope of the data collection effort, there are also trade-offs to excluding areas. For example, if you want statistics on the proportion of various land use/land cover types throughout the landscape, then you would need to include all land use/land cover types. Once the area has been defined and the mapathon completed, it is difficult to recover missing data, so we recommend taking an inclusive approach if there is any uncertainty.

CASE STUDY HIGHLIGHT 3.

Defining the Survey Indicators in Ethiopia

The indicators to monitor restoration as part of Ethiopia's Collect Earth–based Tree Assessment Survey were chosen to reflect the contributions of trees to human well-being and ecosystem health. As trees provide different bundles of ecosystem goods and services based on their locations in the landscape, it is important to differentiate by land use/land cover type. For example, trees in settlements can mainly provide food, shade, carbon sequestration, and beautification whereas trees in croplands can mainly provide woodfuel, erosion control, soil fertility, microclimate control, and carbon sequestration. Additionally, trees within the same land use can be associated with different ecosystem goods and services based on their spatial patterns (e.g., clustered versus scattered) so it is important to distinguish spatial patterns. Trees along farmland boundaries and trees scattered within the field are likely not there for the same reason: Farmers might plant trees along farm boundaries as sources of timber or woodfuel, while they might scatter trees on a field to increase the productivity of cropland or grazing land.

As a result, national, regional, zonal, and district experts identified the following indicators to monitor trees in Ethiopian landscapes, with a focus on their contributions to human well-being and ecosystem health:

1. Land use/land cover type—to quantify areas of forest and other land use/land cover classes where tree-based interventions are taking place or could take place. Thirteen classes were adapted from the national land use/land cover classes to reflect restoration targets (e.g., high forest versus dense woodland) and the national restoration options (MEFCC 2018).

2. Percent tree cover—to assess the presence and distribution of trees throughout the woreda (i.e., across all land use/land cover classes) by land use/land cover class on land treated with restoration interventions and in gullies.

3. Spatial distribution of trees—to assess the specific spatial distribution (i.e., scattered, clustered, linear pattern, and regular pattern) of trees in cropland, grassland, rural compound, and settlement.

4. Percent of linear features with tree canopy—to assess the presence of trees along specific linear features (i.e., waterbody banks, boundaries, bunds/terraces, roadsides, and gully banks).

The mapathon to collect data on tree cover and distribution in Ethiopia took place for Sodo Guragie woreda (district). Districts must report every five years on their progress toward the goals stated in the Growth and Transformation Plans. While the area of interest for the mapathon focused on only one district, the survey was designed to be of national relevance. The district was chosen based on local stakeholder interest and existing work by the National Forest Sector Development Program.

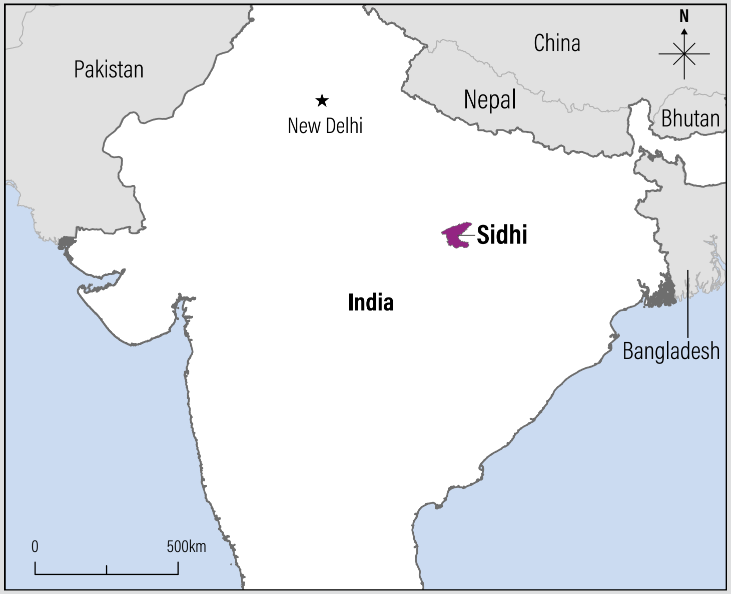
CASE STUDY HIGHLIGHT 4.

Defining the Survey Indicators in Sidhi, India

The mapathon for Sidhi District, located in the state of Madhya Pradesh in central India, was conducted as part of an assessment of landscape restoration opportunities in the district (Figure 6). Prior consultations with stakeholders revealed that the district is facing critical land use challenges that need to be addressed to improve the productivity of land and secure the livelihoods of the dependent population. These challenges include loss of natural forests, high dependence on fuelwood, lack of common land and pastureland, and declining productivity of agriculture land (Singh et al. 2020).

Stakeholders also informed us that landscape restoration interventions such as agroforestry and farm forestry are already being practiced in the district for a range of benefits including erosion control and provisioning of fodder and fuelwood. Survey indicators for the mapathon were therefore designed to collect information on the landscape, which would aid in planning landscape restoration for multiple ecosystem services in the district. Since collecting indicators data required deep knowledge of the landscape, stakeholders from Sidhi were invited to participate in the mapathon. To better leverage the knowledge of participants, questions requiring some interpretation about the landscape were included in addition to biophysical indicators. The list of biophysical and qualitative survey indicators used for the Sidhi mapathon are presented in Table 6.

Figure 6 | Location of the Case Study: Sidhi District, India



Note: This map is for illustrative purpose and does not imply the expression of any opinion on the part of WRI, concerning the legal status of any country or territory or concerning the delimitation of frontiers or boundaries. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Source: Map produced at WRI using data from Survey of India.

Table 6 | Biophysical and Qualitative Indicators Used for the Sidhi District Mapathon

CATEGORY	BIOPHYSICAL INDICATORS	QUALITATIVE INDICATORS WITH OPTIONS	OPEN-ENDED QUALITATIVE INDICATORS
Land use	▪ Present land use ▪ Land use change	▪ For forest land, type of forest (e.g., natural, monoculture plantation, mixed plantation) ▪ For agricultural land, status of irrigation (irrigated or rain-fed)	▪ Driver of change in land use ▪ Source of irrigation (e.g., well, canal) ▪ Types of crops grown (e.g., rice, maize, millet, pulses)
Tree cover	▪ Percent tree cover ▪ Tree count ▪ Change in tree count	None	▪ Tree species ▪ Drivers of change in tree cover ▪ Drivers of change in tree species
Pattern of trees in agricultural land	▪ Presence of trees in farmlands	None	▪ Pattern of trees in agricultural lands (e.g., trees on boundaries, alley cropping, farm forestry) ▪ Potential to expand trees in the plot ▪ If trees are present in farmlands, what type of intervention can be implemented and what benefits would accrue?

Source: Authors.

CHAPTER 4:

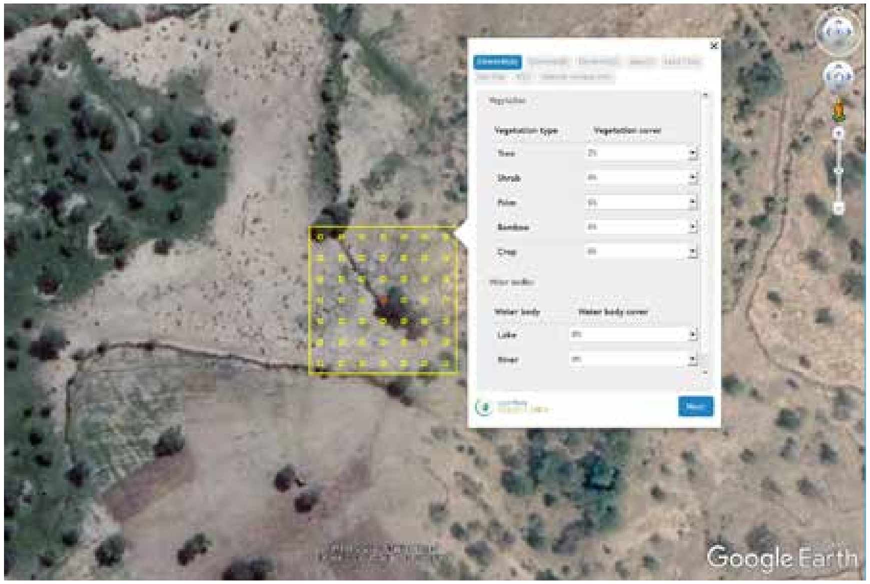
STEP 3: DESIGN THE SURVEY

Once you have identified the indicators for which you want to collect data, the next step is to design the Collect Earth survey, which involves composing and structuring questions to elicit the desired information from the data collector.

Designing the survey requires thoughtful phrasing to be sure the data collectors input the precise data of interest. For example, if one of your indicators is percent tree cover, then you need to include a survey question that asks data collectors to identify the proportion of the sample plot that is covered by tree canopy. Collect Earth surveys are customizable and can be modified to capture the variety of indicators selected in Step 2 and in a context that aligns with the data use plan.

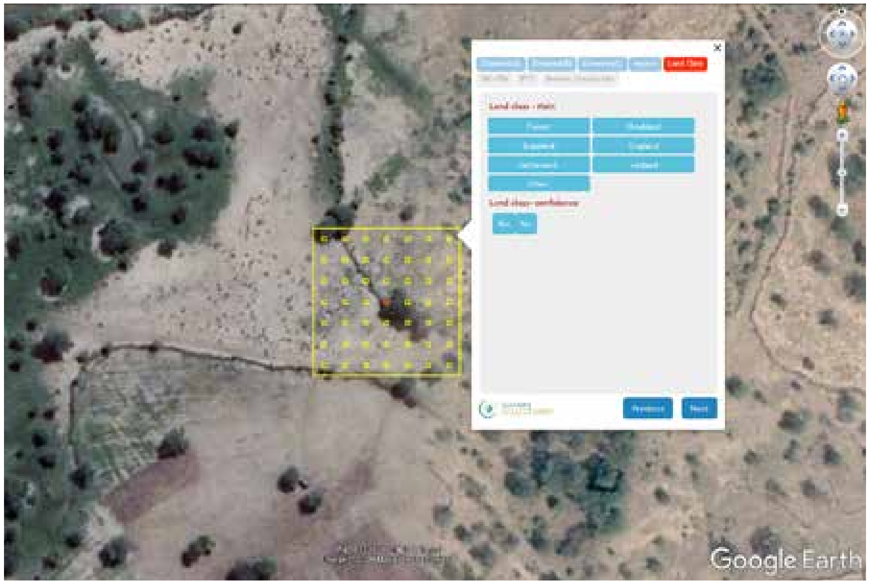
For the desktop version of Collect Earth, the survey needs to be created and configured within a separate survey design tool called Collect, which is downloadable from the Open Foris suite of tools. Surveys are organized into separate panels of questions called "cards," which help structure information by theme and better drive the logic of the survey questions. The cards are navigated via a series of tabs at the top. Two sample survey cards are shown in Figures 7 and 8. In Figure 7, the "Elements(A)" card refers to elements of the landscape, where the data collector identifies the proportion of vegetation cover for each listed vegetation type, and proportion of water body cover for each listed waterbody type. In Figure 8, for the "Land Class" card, the data collector selects the main land use/land cover type for the entire plot. In the screenshot, the yellow box defines the sample plot, and the yellow dots are the control points. The red control point identifies the center of the plot. The control points are useful for estimating tree cover within the sample plot. For example, instead of counting individual trees throughout

Figure 7 | Sample Survey Card on Vegetation and Water Body Types Using the Desktop Version of Collect Earth



Note: The "Elements (A)" card (shown here) refers to elements of the landscape, where the data collector identifies the proportion of vegetation cover for each listed vegetation type, and proportion of water body cover for each listed waterbody type. In the screenshot, the yellow box defines the sample plot, and the yellow dots are the control points. The red control point identifies the center of the plot.
Source: Satellite image from Google Earth via Collect Earth. Survey produced by FAO.

Figure 8 | Sample Survey Card on Land Class Using the Desktop Version of Collect Earth



Note: For the "Land Class" card (shown here), the data collector selects the main land use/land cover type for the entire plot. In the screenshot, the yellow box defines the sample plot, and the yellow dots are the control points. The red control point identifies the center of the plot.
Source: Satellite image from Google Earth via Collect Earth. Survey produced by FAO.

the plot, the data collector can count the number of tree crowns touching a control point. This number can then be converted into a percentage of tree cover per sample plot.

In Collect Earth Online, the survey design process is slightly different in that the questions are drafted using templates for various types of questions (e.g., multiple choice, fill-in-the-blank) within the survey design section of the project setup interface. The case studies featured in this guide all used the desktop version of Collect Earth and customized the survey cards to capture information targeted to their national context and goals. See Case Study Highlight 5 for an example of how the survey was designed for the mapathon in Ethiopia.

The data collected from the survey questions are output in spreadsheet format as a series of "attributes" (i.e., columns or fields in the spreadsheet) that are associated with each sample point by an identification number. It is possible to pre-populate the spreadsheet with additional descriptive attributes for a sample plot that does not need to be collected within the survey. For example, you can associate the sample plot with an administrative location, such as a district, or other spatial information, such as slope, elevation, or biome, input from another data source using GIS (geographic information systems). We recommend including these types of descriptive attributes because they improve your ability to summarize and visualize the results at a spatial scale that is meaningful to your stakeholders. In Figure 9, for example, the input grid contains a "region" attribute that will later make it possible to summarize and present the survey results aggregated by region.

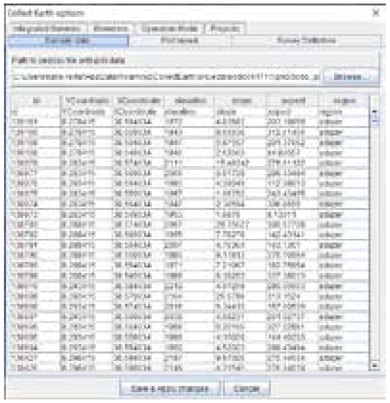
Tip: Use "Validation Rules" within Survey Questions to Limit Human Error

"Validation rules" can be coded into the survey to establish parameters that need to be met for a certain response to be valid, helping to reduce the potential for human error. For example, the tree cover percentage for a sample plot can only be a numeric response between 0 and 100; if a data collector's response is non-numeric or exceeds 100, an error message will result. At a minimum, we recommend that you establish rules that ensure that all key questions in the survey are answered. A common source of error occurs when data collectors accidentally skip a question when moving quickly through a survey. To prevent this error from occurring, a rule can be set up such that the data collector cannot save their responses and move on to the next sample plot until the missing response has been provided.

Tip: Consider Including Qualitative Survey Questions

While it is most common to include survey questions that are based strictly on visual interpretation of the imagery, it is possible to include questions that collect qualitative information. These types of questions are most suitable when the data collectors are from the local community or are otherwise very familiar with the landscape. In the Sidhi District in India, for example, qualitative questions solicited information on the drivers of deforestation, reasons for particular patterns of tree cover on farmlands to understand the flow of ecosystem services, and the potential to expand tree cover. It is important to note that the data collected from qualitative questions reflect the perceptions and experiences of the participants; therefore, conducting additional field verification of the data would be pragmatic prior to drawing any definitive conclusions or making major decisions. See Case Study Highlight 6 for more detail on how qualitative questions were integrated into the survey for the mapathon in India.

Figure 9 | Adding Attributes to the Collect Earth Survey to Improve the Data Analysis Process



Source: Collect Earth and authors.

Tip: Reduce Time Cleaning Data by Simplifying the Survey

To reduce time spent interpreting and cleaning the data after the data collection process has ended, you can design the survey to include dropdown menus or multiple-choice options as opposed to open-ended or fill-in-the-blank-style questions. In India, for example, data on tree species and crops were collected using a text box. A narrower dropdown list of known species with a text box option to write in "other" species not part of the dropdown list would have saved time when data cleaning by avoiding having to manually categorize data and fix typographical errors.

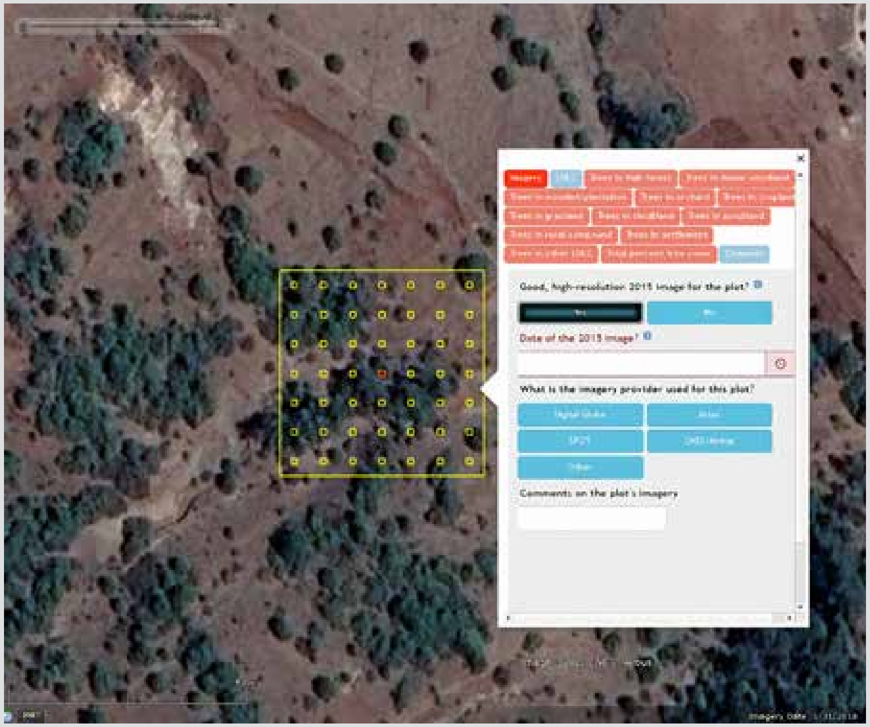
CASE STUDY HIGHLIGHT 5.

Designing the Survey in Ethiopia

Once the indicators were identified, a Collect Earth desktop survey was designed to collect data for them. The Tree Assessment Survey developed for Ethiopia had 24 cards, where a "card" is a series of survey questions organized by theme (Figure 10). Cards appear only when relevant to what the expert reports seeing in the plot. For example, the "Trees along roads" card appears only if the expert states that there is a road in the plot. Each card has fields for which the expert enters data based on their interpretation of the image. The more the expert knows about the plot, the more details they can enter. For example, experts conducting a national assessment, if unfamiliar with local conditions, will not be prompted to identify the dominant tree species in the plot. Local experts, if knowledgeable about the plot, will be prompted to make such identification. Accommodating various degrees of local knowledge enables the Tree Assessment Survey to ensure vertical integration across scales and consistency in data collection without sacrificing local information.

Within each sample plot, experts collected data by counting the number of control points on trees in particular land cover types (Figure 11) and, when relevant, measuring the length of linear features (Figure 12) with trees. For each piece of data collected, experts also stated whether they were confident in their interpretation or not. The survey used official definitions when they existed to be consistent with other mapping and monitoring efforts.

Figure 10 | Collect Earth Tree Assessment Survey Cards Developed for Ethiopia



Good, high-resolution 2015 image for the plot?

Date of the 2015 image?

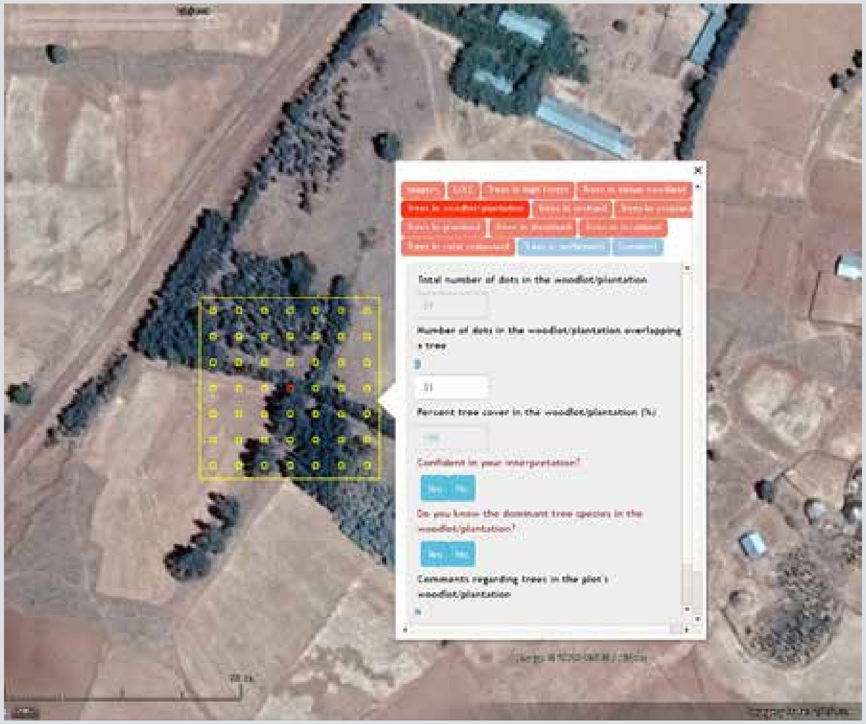
What is the imagery provider used for this plot?

Comments on the plot's imagery

Note: Ethiopia's Tree Assessment Survey had 24 cards. The red and blue color scheme indicates complete (blue) and incomplete (red) cards. Once all of the required fields (i.e., fields for which data must be entered) are filled in, a card turns blue.

Source: Satellite image from Google Earth via Collect Earth. Survey produced by Environment, Forest and Climate Change Commission (Ethiopia) and WRI.

Figure 11 | Counting Control Points (Dots) to Estimate Tree Cover Using Collect Earth



Total number of dots in the woodlot/plantation

Number of dots in the woodlot/plantation overlapping a tree

Percent tree cover in the woodlot/plantation (%)

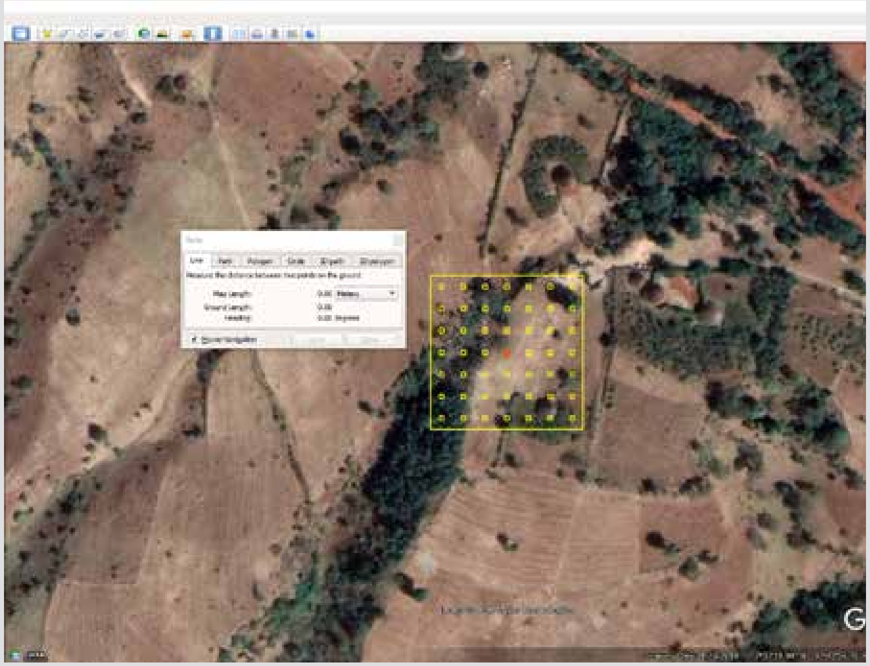
Confident in your interpretation?

Do you know the dominant tree species in the woodlot/plantation?

Comments regarding trees in the plot's woodlot/plantation

Note: Ethiopia's Tree Assessment Survey cards had three types of fields: calculated fields (grey), required fields for which data must be entered (red), and optional fields (black). This card, titled "Trees in woodlot/plantation," asked the user to input data on the number of dots in that land use/land cover that touch a tree, and calculated the percent tree cover based on the input data.
Source: Satellite image from Google Earth via Collect Earth. Survey produced by Environment, Forest and Climate Change Commission (Ethiopia) and WRI.

Figure 12 | Measuring Linear Features in Collect Earth



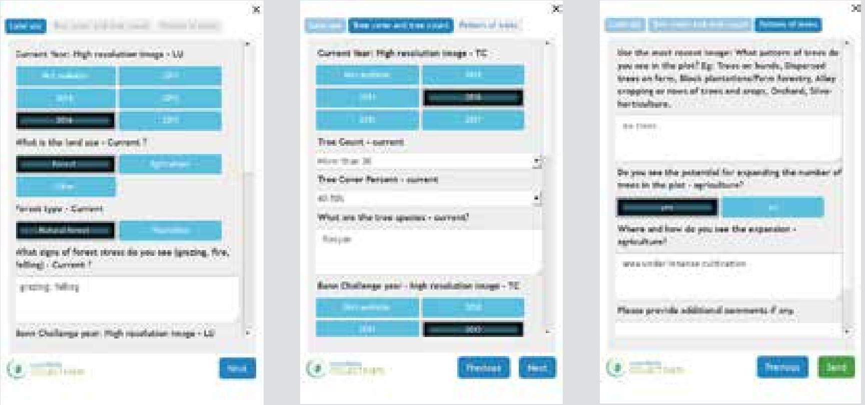
Note: The "Trees along roads" survey card calculated the percent of roads with tree canopy based on the user inputting their measurement of total road length and of length of roadsides with tree canopy.
Source: Satellite image from Google Earth via Collect Earth. Survey produced by Environment, Forest and Climate Change Commission (Ethiopia) and WRI.

CASE STUDY HIGHLIGHT 6.

Quantifying Qualitative Data in Sidhi District, India

In the Sidhi District of India, one of the primary objectives of the mapathon was to better understand the pattern of trees on agricultural land and identify existing agroforestry practices. To acquire this information, the team designed the survey to include semi-structured qualitative questions. These questions asked about the existing patterns of trees on farmlands and the potential to increase tree cover. The survey also gathered qualitative data on the species of trees, signs of irrigation, signs of forest stress, and reasons for change in land use and change in tree species (such as mixed plantation to monoculture plantation or vice versa). Tips and examples were provided to standardize these definitions for participants (Figure 13).

Figure 13 | Collect Earth Survey Cards with Qualitative Indicators



Note: This figure provides examples of survey cards with qualitative indicators that were used to collect data in Sidhi District, India.

Source: Collect Earth and authors.

Data cleaning and organization for these qualitative questions was a lengthy process. Because the qualitative questions were open-ended, the responses had to be manually reviewed and cleaned. Staff with experience in the field participated in the mapathon and carried out the data cleaning. The qualitative questions collected multiple data points per question—such as the patterns of trees, species names, and crops—and thus required additional review and organization to facilitate data analysis. Knowledge from the field through previous field visits helped the data cleaners standardize the data and identify inconsistent information. Data were checked for spelling errors, requiring that standardized species names and local terms be translated into English. Any remaining doubts on local names were clarified with the local experts from the landscape. Some assumptions were made to crosscheck for errors. For example, no tree pattern would be recorded in plots with fewer than three trees. Because of the intensive data cleaning that was needed during the post-processing phase, a key lesson learned for the next mapathon was to format the survey to collect more responses in a multiple-choice format, as opposed to using text boxes that collect open-ended responses. While using a multiple-choice approach requires more background research during the survey design phase to understand what types of responses should be included as options in the survey, it eliminates the extensive review and formatting of responses during the analysis phase. Despite the lengthy data review and cleaning, the collected information was invaluable for providing insight into existing agroforestry practices in Sidhi, and established the inputs for restoration opportunities mapping.

CHAPTER 5:
STEP 4: DESIGN THE SAMPLING SCHEME

Designing the sampling scheme for a Collect Earth survey involves defining the sample plot size and layout and choosing a sampling method for the spatial distribution of plots across the area of interest. You may want to consider aligning these parameters with the national definition of forest as well as the schema for any existing forest inventories to ensure compatibility with existing policies or initiatives.

Collect Earth is a sample-based tool. After identifying the landscape that is the focal area of the mapathon, a scheme for sampling within the landscape needs to be derived. The plot layout, size, and spatial distribution can be modified to maximize compatibility with a country's definition of forest and existing or planned forest inventories. The standard plot area in Collect Earth is set to 0.5 hectares to be consistent with the FAO's definition of forest used in its Global Forest Resources Assessment (FRA). This plot area can be changed to match different national definitions. For instance, in Rwanda, a 0.25-hectare plot was selected to match the national definition of a minimum area to qualify as a forest. As shown in Table 8, each of the four countries defined their forests and plot sizes differently.

Tip: Take Stock of Previous Collect Earth Activities in or near Your Area of Interest

It is worth verifying whether a Collect Earth mapathon has been previously conducted in the country to ensure the efforts are aligned. Liaising with people who were involved in a previous Collect Earth mapathon can provide useful preparatory information. Specifically, ask these experts about the difficulties encountered during the process. If people who have been trained on Collect Earth are located in the country, consider requesting their support to prepare for or assist during the mapathon.

For the spatial distribution of the plots, we recommend using the same sampling design as the national grid for forest inventories. If such a grid does not exist or if it is not well suited to monitor the restoration interventions, a grid of sample plots can be created using QGIS, Google Earth Engine (via the Collect Earth grid generator), ArcGIS, SEPAL, or similar geospatial software. In terms of the spacing of the plots (for systematic sampling design) and the sampling intensity, standard statistical procedures apply. In general, the experts developing the sample design consider factors including the heterogeneity of the study area and the level of accuracy expected when calculating the sample size and sampling intensity. There are trade-offs to consider, particularly between accuracy and time. For example, a dense sample grid (large sample size) would have a high level of accuracy when using the collected data to make summary statistics of the whole area, but would require a significant amount of time to classify many plots. Conversely, a sample grid with plots spaced far apart (small sample size) would take less time to classify but at the expense of accuracy. For more information on how to structure your sample, we recommend consulting the guidebook *Map Accuracy Assessment and Area Estimation: A Practical Guide* (FAO 2016).

The heterogeneity of the landscape is important to consider because you want to sample all types of land uses multiple times. A highly heterogeneous landscape (many land uses) requires more samples so that each land use type has adequate coverage.

CHOOSING A SAMPLING METHOD

The sampling methods can be classified in two main categories:

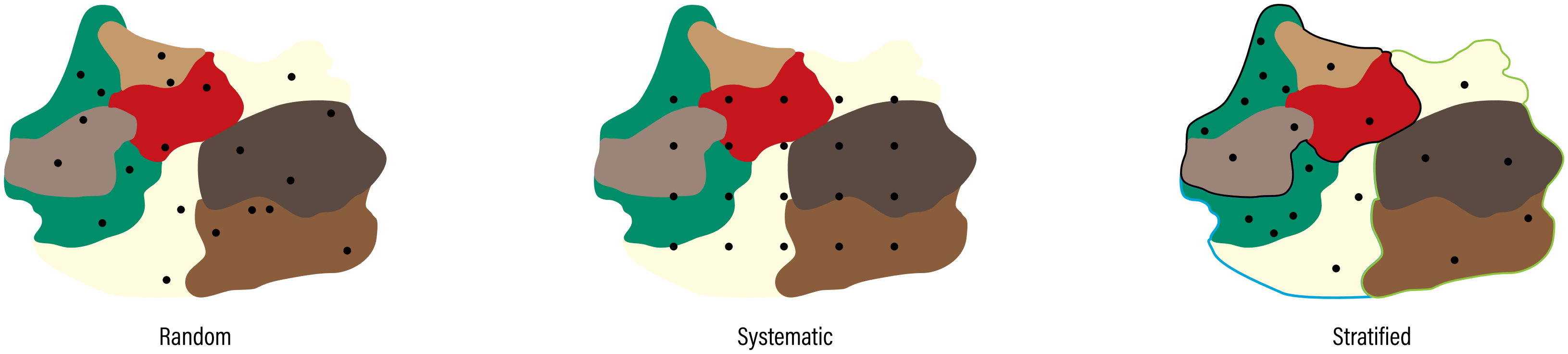
- **Random:** Random sampling consists of sample plots located randomly across the area of interest.

- **Systematic:** Systematic sampling uses a grid of equally distributed sample plots across the landscape.

Within each of these categories, it is also possible to incorporate stratification. Stratified sampling involves dividing the landscape into subareas that share similar conditions, such as by land use/land cover type (e.g., wetlands, riparian zones, upland forests), and distributing the sample plots randomly or systematically within each subarea (Figure 14).

Each of these methods has advantages and disadvantages depending on your goals for the assessment (Table 7).

Figure 14 | Three Types of Sampling Schemes



Source: Authors.

Table 7 | Advantages and Disadvantages of Sampling Methods

SAMPLE METHOD	ADVANTAGES	DISADVANTAGES
Random	■ Requires minimal prior research of the variability of different land use categories across the landscape.	■ If the area under assessment is highly heterogenous (a mosaic of different land uses), then a random set of sample plots may misrepresent some land use classes due to low sample size of those land use classes
Systematic	■ Provides even and consistent coverage of the entire area under assessment with sample plots.	■ If there is a mismatch between the distribution of specific land use/land cover types and the distribution of sample plots, the results can be severely biased.
Stratified (random or systematic)	■ Ensures adequate representation of each subunit by distributing the samples according to the proportion or expected variability of the subunits (e.g., land use/land cover categories).	■ Requires more preparation time to compile the relevant information about the landscape to stratify the area according to the specific context.

Source: Authors.

Table 8 provides examples of how the sample was designed in each of the country case studies. Note how the national definition of forest influenced the plot size in each case study.

Tip: Use Official Definitions and Existing Information

Aligning with national definitions and forest inventory sampling design, and other existing monitoring procedures at the country level, will facilitate the transfer of information from the project to the national, regional, and international levels. If the national level uses different definitions than those you are using for your Collect Earth mapathon, you will not be able to compare the local data with the national data, which means that the data you collect will not be recognized as meaningful at the national level.

Table 8 | Examples of Sample Design from Each Country Case Study

COUNTRY	NATIONAL DEFINITION OF FORESTS	SAMPLING METHOD	SAMPLE CREATION	PLOT SIZE	TOTAL PLOTS
El Salvador	A minimum of 0.5 hectares with 30 percent crown cover at a minimum height of 4 m.[a]	Systematic	Every 250 m	0.5 ha	6,750 plots
Ethiopia	Legally, forest is defined as "trees, plants and other bio-diversity accumulation at and in the surrounding of forest lands, roadsides, riverside, farm and grazing lands as well as residential areas or parks that grow naturally or developed in some other ways."[b] Technically, forest is defined as "land spanning at least 0.5 ha covered by trees (including bamboo) attaining a height of at least 2 m and a canopy cover of at least 20% or trees with the potential to reach these thresholds in-situ in due course."[c]	Stratified random	Minimum of 30 plots for each *kebele* (the smallest administrative unit in Ethiopia)	0.5 ha	2,410 plots (2010) 2,452 plots (2015)
India	The recorded forest area refers to all geographic areas categorized as "forest" in government records. Forest cover includes all areas more than 1 ha in extent and having tree canopy density of 10% and above irrespective of land use and legal status.[d]	Systematic	Every 1 km	1 ha	3,810 plots
Rwanda	Defined by the Department of Forests and Nature Conservation in the Rwanda Water and Forest Authority as land spanning more than 0.25 hectares with trees higher than 7 m and a crown cover of 10 percent.[e]	Systematic	Every 600 m	0.25 ha	3,937 plots

Notes: The abbreviation m stands for meters, ha for hectares, and km for kilometers.

a. MARN 2019.

[b] FDRE 2017.

[c] MEF 2015.

[d] FSI 2017.

[e] CGIS-NUR et al. 2012.

Source: Authors.

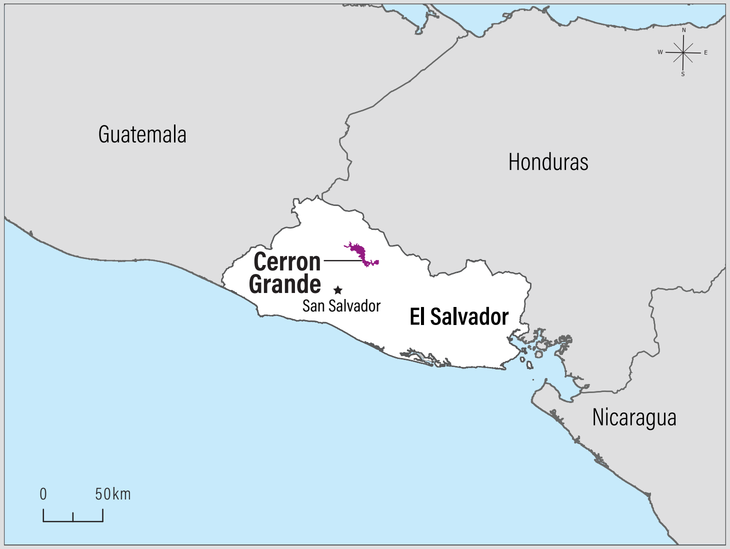
CASE STUDY HIGHLIGHT 7.

Designing the Sampling Scheme in El Salvador

El Salvador pledged to the Bonn Challenge and Latin America and Caribbean–focused Initiative 20x20 to restore 1 million hectares (approximately half of the country area) of degraded and deforested land. To develop strategies for restoration and to monitor progress, the government of El Salvador supported the Collect Earth mapathon. The mapathon focused on a strategic area for water catchment recharge—the Cerrón Grande watershed in the north-central region of the country—that helps meet water demand from the capital (Figure 15).

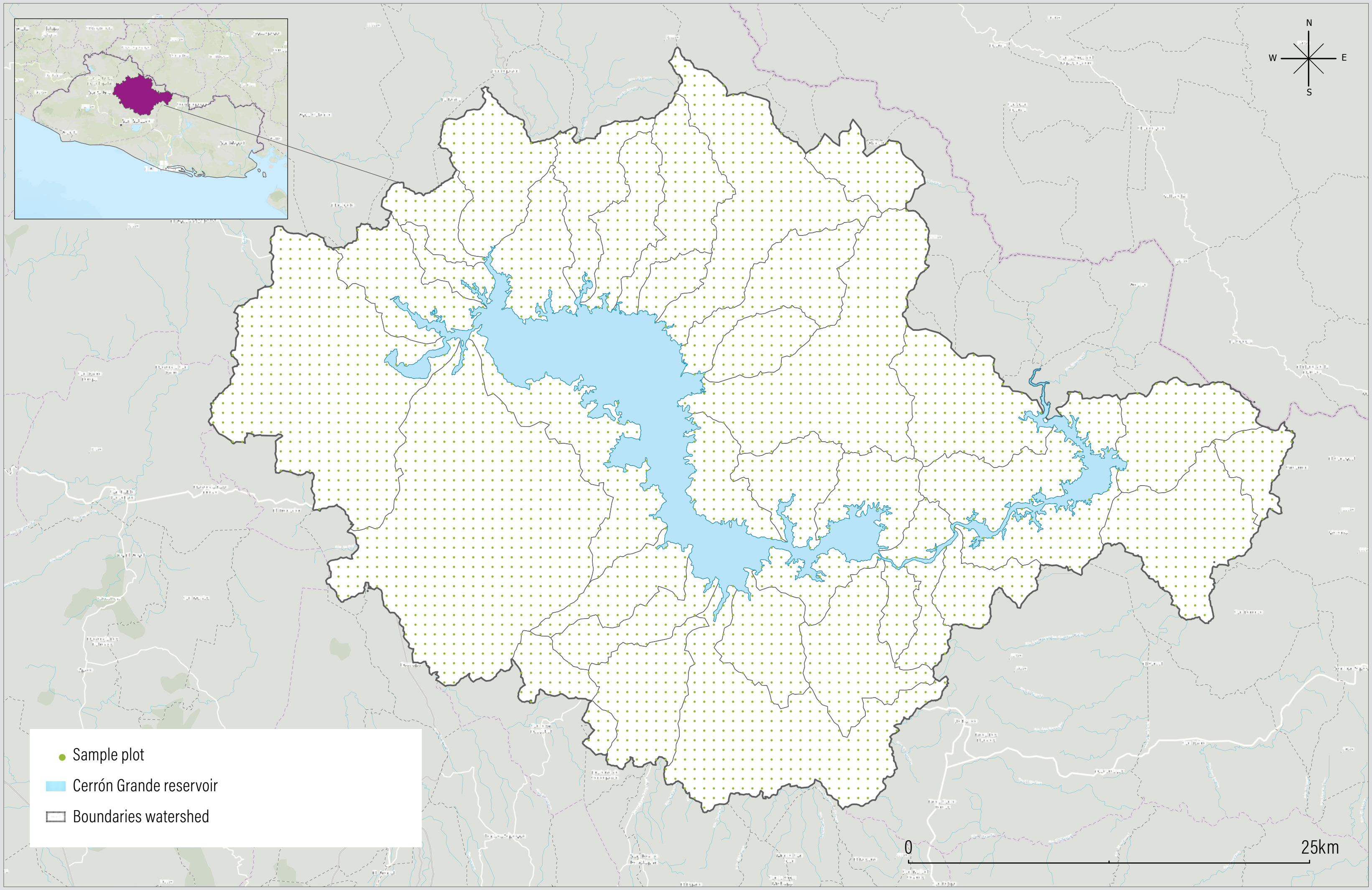
The objective of the mapathon was to explore changes in forest cover between 2000 and 2016 as well as to estimate the number of trees outside forests. Collect Earth was also used to develop a land use/land cover map that could serve as input for other analyses related to connectivity and potential carbon estimation. The land use/land cover map was chosen as a product to measure the level of connectivity in priority landscapes and other important aspects of the landscape. Because one of the objectives was to produce a land use/land cover map, the stakeholders implemented a systematic sampling grid of plots spaced every 250 meters (m) (Figure 16). The relatively dense number of plots for the size of the watershed meant that the resulting map would have a greater amount of detail and data points for producing the map than a sparser sample scheme. Knowing what products and communication tools you intend to produce with the Collect Earth data, such as maps, affects each step of the mapathon process, including developing the sampling scheme, so it is important to make those decisions at the earliest stages of the process.

Figure 15 | Location of the Case Study: Cerrón Grande Watershed, El Salvador



Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Source: Map produced at WRI using data from IGCN (n.d.).

Figure 16 | Sampling Scheme for the Collect Earth Survey in Cerrón Grande, El Salvador


N
W
E
S
● Sample plot
▭ Cerrón Grande reservoir
▭ Boundaries watershed
0
25km

Source: Map produced at WRI using data from Esri and OpenStreetMap.

CHAPTER 6:
STEP 5: ORGANIZE THE MAPATHON

Mapathons require several weeks of advanced planning to ensure that all logistical and technical arrangements are in place. Investing ample time and resources in recruiting data collectors, thinking through the amount of time needed for training and data collection, finding a suitable venue to host the event, and ensuring that the appropriate equipment is in place will maximize the success of the mapathon.

Organizing a mapathon requires several weeks of preparation to set up logistical and technical arrangements. Reach out to local, regional, or national decision-makers early in the planning stages of your mapathon. Getting their support for the data collection effort can facilitate preparation by improving coordination or making it easier to find suitable data collectors. In addition, buy-in from decision-makers will allow the data collected to more quickly lead to improved action and implementation. In some cases, that may include designing the mapathon collection process—the survey cards, sample plots, and area of interest—with the decision-makers. The following series of activities provides an overview of the logistics that are important to consider when organizing your mapathon. This series was designed based on the experiences of the four case study countries with their mapathons.

Tip: Build In Time and Resources to Identify Data Collectors

Identifying data collectors from the landscape can be a long process since it requires convincing people to put aside their day-to-day work to participate. Incentives such as a daily stipend may help alleviate this challenge. In addition, you may consider highlighting the technical training one can gain from participating. Carefully explain the objectives, process, and potential outcomes of the mapathon, and how the mapathon will benefit the community.

1. IDENTIFY POTENTIAL DATA COLLECTORS

Work with key stakeholders and partners to make a list of good candidates for participants in the mapathon. Consider seeking people from universities, local NGOs, and other local organizations, as well as members of the community. Prioritize women, youth, and members of marginalized communities, as each perspective brings different lived experiences that will impact how the collected data will be interpreted. Data collectors do not need GIS or remote sensing skills, though having familiarity with maps and interpreting imagery is beneficial. At a minimum, basic computer literacy and understanding of maps are required, and knowledge of the area to be assessed is strongly preferred. The amount of training will need to be adjusted depending on the data collectors' levels of experience.

Tip: Engage Local Communities in Monitoring

Consider adding a participatory process that pairs individuals from the local community with more experienced data collectors to capture local knowledge on restoration, the progress of the restoration, and the overall change to the landscape. In the Sidhi District of India, members from local communities, particularly farmers and youth, helped interpret and collect data. Each community member was paired with a student or young professional trained in how to use Collect Earth. The pairs analyzed satellite imagery together, adding a nuanced understanding of land use, land use change, tree species, and crops.

Tip: Collaborate with Academic Institutions

Universities and other academic institutions are often a good source of mapathon participants with technical skills in geospatial tools and interest in restoration monitoring. Involving people from academia is also a good way to build sustainability into the monitoring process, since lecturers may be able to incorporate the Collect Earth tool and mapathon approach into their curricula, thereby ensuring that training and data collection occur at regular intervals. They are also well-positioned to provide the venue and necessary equipment to host the mapathon (i.e., a computer lab) at little or no cost. An added benefit for students and lecturers is that they can incorporate the collected data into their research projects.

2. SCHEDULE AN APPROPRIATE AMOUNT OF TIME FOR THE MAPATHON

The mapathon should be as short as possible while providing enough time for training, practice, data collection, and consensus-building around satellite image interpretation. In Ethiopia and Rwanda, organizers planned for 1.5 days of training for 20 people, and both groups felt that more training on how to interpret images would have improved data quality.

The numbers of days for the mapathon will depend on the following:

a. The amount of time needed for training

b. The number of plots to assess (i.e., the size of the area of interest)

c. The number of participants

Based on our experience, we have found that one trained data collector can assess an average of 100 plots per day at the typical rate of five minutes per plot using the default survey template. Also, we recommend starting the mapathon with at least two full days of training. More days can be added to the training component if one of your goals is to strengthen the capacities of the data collectors in using Collect Earth. We recommend dedicating a minimum of one week to a mapathon, while two or more weeks may be necessary for larger areas.

Tip: Conduct Introductory Training for Participants before the Mapathon

If time and resources permit, we recommend conducting a training session via webinar, conference call, or another remote-access meeting method. In Sidhi District, before the mapathon the organizers conducted a webinar for the technical participants that covered the objectives of the mapathon, introduced the landscape, and provided an overview of the types of questions the survey would ask. While this type of information can be emailed in advance, conducting a meeting enabled the organizers to confirm that participants had received and digested the materials, and it fostered a sense of community among the participants before they gathered for the event.

3. SELECT A VENUE

The major considerations in selecting a venue for the mapathon include its accessibility to participants, the availability of a strong internet connection, and rental fees (if applicable). It is important to note that there are often trade-offs between accessibility and the availability of infrastructure. While conducting the mapathon within the landscape itself is ideal for encouraging maximum local participation, a lack of infrastructure, such as internet service and meeting space that can accommodate many computers, would limit this option, particularly in rural areas. It may take some time to identify a suitable location that is reasonably accessible to participants but also has the appropriate infrastructure. It is highly recommended to use a computer lab or otherwise provide computers so that participants do not have to bring their own laptops. Universities are often a good option to consider for this type of arrangement.

4. GATHER THE REQUIRED EQUIPMENT

Required equipment to conduct a mapathon includes computers for all participants, and a projector or large screen to use for training. Optional equipment includes USB (flash) drives to share files, a device to extend an internet connection, and dual monitors for each person. If the venue or your organization is not providing computers, you will need to ask participants to bring their own laptops. Be aware that participants may bring very old machines or ones of varying quality, and if you are using the desktop version of Collect Earth you will need to reserve time in the agenda to install all required software (e.g., Collect Earth, Google Earth, Firefox, Chrome) on the computers; Collect Earth Online does not require software installation. If you are providing computers to the participants, we recommend that you install the required software in advance and test it on each computer to minimize time spent on logistical and technical setup once the participants have arrived.

Tip: Have IT Support On-Site to Troubleshoot Computer Issues

We recommend that you have a dedicated information technology (IT) staff person available for the duration of the mapathon to troubleshoot computer, internet, and software issues; this is especially important if data collectors bring their own laptops.

5. DEFINE THE AGENDA

Typically, a mapathon starts with an introduction, equipment installation (if necessary), and training on how to use the tools and how to interpret imagery. The subsequent days are dedicated to data collection. The time for data collection will increase if more questions are added, or if the survey includes more complex questions. The exact daily schedule will vary depending on the work habits in the country but will usually last approximately eight hours per day, with 15-minute breaks every two hours or so.

Tip: Pilot Test the Survey to Help Estimate the Amount of Time Needed for Data Collection and Double-Check the Survey Questions for Clarity

When organizing your mapathon, pilot each survey with several people with and without Collect Earth experience to estimate the time each survey will take to complete. You can use the average time to determine how many people and how many days it should take to complete the data collection process in your landscape. Pilot testing will also help show if there are any portions of the survey that are unclear or overly complex; fixing these portions in advance will improve the results, as well as reduce time spent during the mapathon providing support to data collectors.

Tip: Consider How Breaks and Complexity of the Survey Will Affect the Time Required

While your ultimate goal is to complete the survey, allocating enough time for breaks is crucial to the process. In Rwanda, organizers included short breaks, online games such as Kahoot! to test the skills of data collectors, and preliminary data presentations. These methods helped avoid fatigue and reduce the potential for errors.

6. SEND THE INVITATION TO THE DATA COLLECTORS

The invitation should include some background information about Collect Earth, why the Collect Earth mapathon is being conducted, the expected output, and learning goals along with the venue location and agenda. It is also important to provide details about whether transport will be organized to and from the venue and whether costs of the mapathon and associated travel, accommodations, and meals will be covered by the organizers so that data collectors can factor in any costs when deciding whether to participate.

If data collectors need to bring their own laptops, that detail should be included in the invitation as well. You may consider providing information about how to download and install the Collect Earth tools in advance to help save time on the first day of the mapathon, though you should still build in time for this in case some participants have not done so or need to troubleshoot the process.

Important: The invitation should also ask all data collectors to sign up for a Google Earth Engine account at least one week before the mapathon, as it can take up to a week to confirm access to an account. Note that participants will need Gmail accounts to acquire a Google Earth Engine account—those who do not already have one will need to sign up for an account first.

7. DEVELOP A PRE- AND POST-MAPATHON EVALUATION SURVEY

Evaluating the quality of the training and the success of the mapathon is important to improve future mapathons. A simple way to do this is to develop Google Forms in advance and ask participants to fill out one survey at the beginning of the mapathon and one at the end. An initial survey could collect information such as demographics, where data collectors work, what their expectations are for the mapathon, and if they have experience working with maps or GIS tools. The follow-up survey could ask whether the training met their expectations, what they learned from the experience, what specific components could be improved, whether the experience changed their perceptions about monitoring or restoration, and if they are interested in participating in future mapathons.

Tip: Provide Certificates to Participants after Completing the Mapathon

Participants often feel encouraged and gratified at the end of a mapathon when a certificate of completion has been distributed to them. It is also something they can share with their supervisors or colleagues to demonstrate that they have received training in Collect Earth and restoration monitoring. Consider preparing such a certificate for all participants before the mapathon.

CHAPTER 7:
STEP 6: CONDUCT THE MAPATHON

The mapathon event involves a few key activities: training the data collectors, conducting the survey, and assessing the data quality. Having a team of Collect Earth experts in the room to answer questions and support real-time assessments of data quality will help to increase the robustness of the collected data.

Conducting the mapathon with a group of data collectors involves three main components:

1. Providing hands-on training on how to interpret satellite imagery for the Collect Earth survey
2. Conducting the survey
3. Conducting a self-assessment of data quality

These components are described in more detail in this section.

8.1. TRAIN DATA COLLECTORS ON HOW TO VISUALLY INTERPRET SATELLITE IMAGES

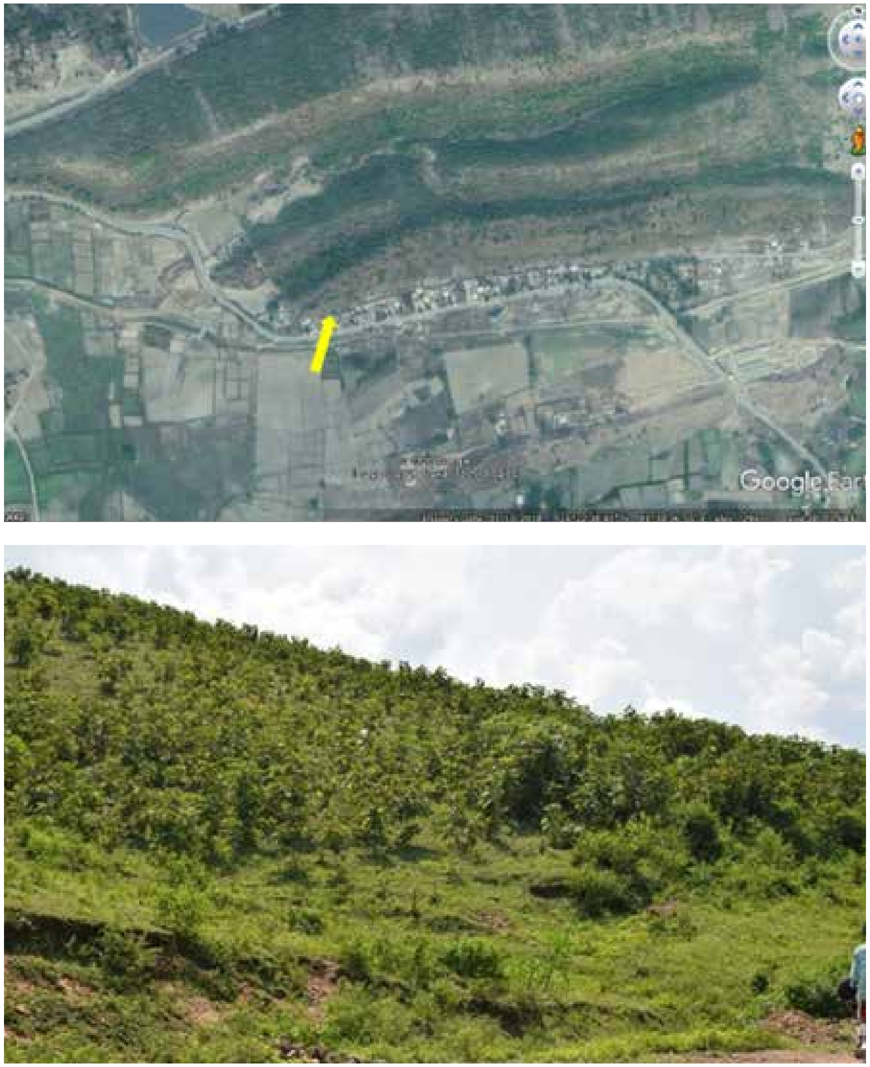
The training component of the mapathon is crucial for familiarizing the data collectors with what to expect from a Collect Earth survey. The content and amount of time spent on training will depend on the data collectors' levels of experience. It is important to spend time not just on how to operate the Collect Earth survey, but also on how to interpret very-high-resolution satellite imagery (e.g., DigitalGlobe images).

Landscape features look different when viewed from the top-down perspective of satellite imagery versus what is seen on the ground. Even if data collectors are highly familiar with the area of interest, it helps to walk them through how to interpret imagery to identify various land use/land cover types and landscape features. Exploring the imagery in Google Earth, Bing Maps, or another source or providing screenshots of imagery from the landscape will help familiarize the data collectors with how features will appear when conducting the survey. It will also help increase consistency across data collectors.

It is important to keep in mind that seasonality may affect how land presents itself. When possible, engage stakeholders that know how seasons affect the land and water bodies and train data collectors using examples of imagery from different times of the year. For example, trees may lose leaves or water bodies may be dry during certain seasons; therefore, it is important to understand how the date of the imagery may affect interpretation.

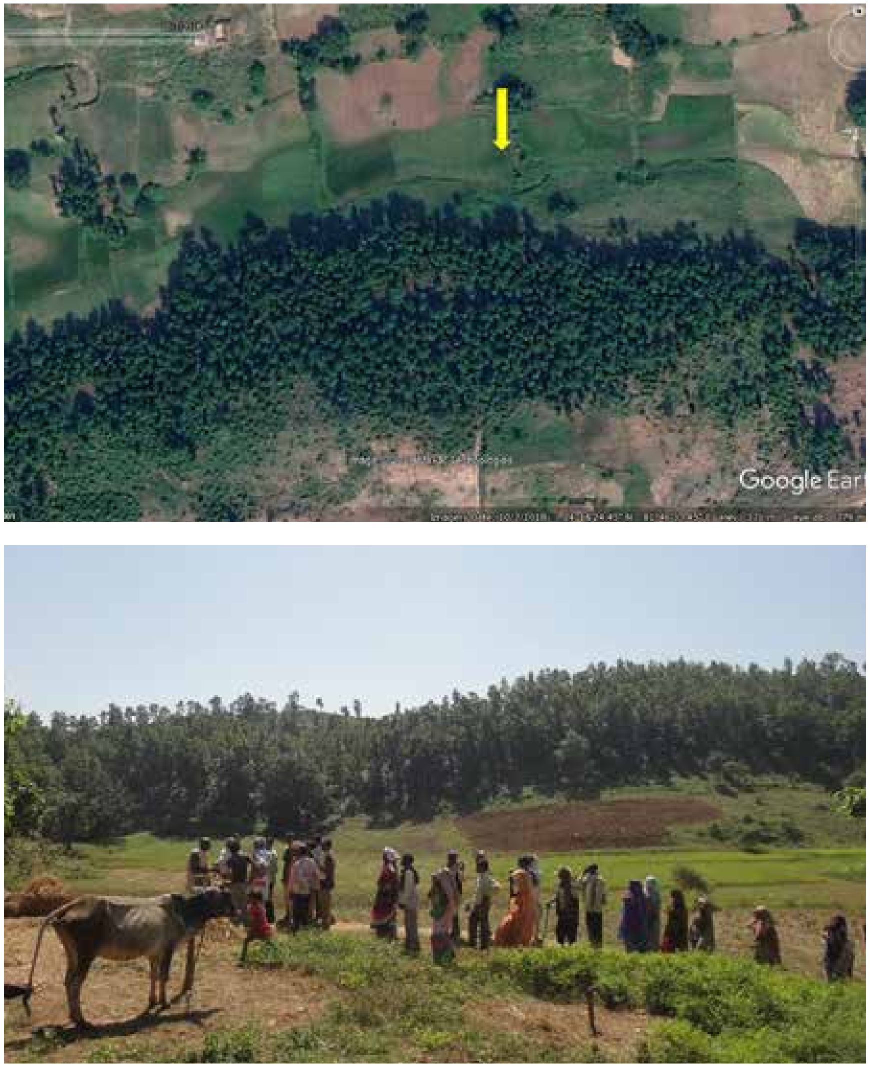
The following images from India and Rwanda provide examples of imagery interpretation (Figures 17–23). In India's Sidhi District, participants from the landscape did not have experience viewing satellite imagery. Many of these participants found it jarring to make the connection between a satellite image and the reality in their landscape. This challenge was overcome by providing examples of each type of land use/land cover so participants could discern patterns in satellite images and then compare those to features they were familiar with.

Figure 17 | Comparison of a Satellite Image (Top) with the Corresponding Field-Level Image (Bottom) for a Plantation in the Beldah Region of Sidhi, India



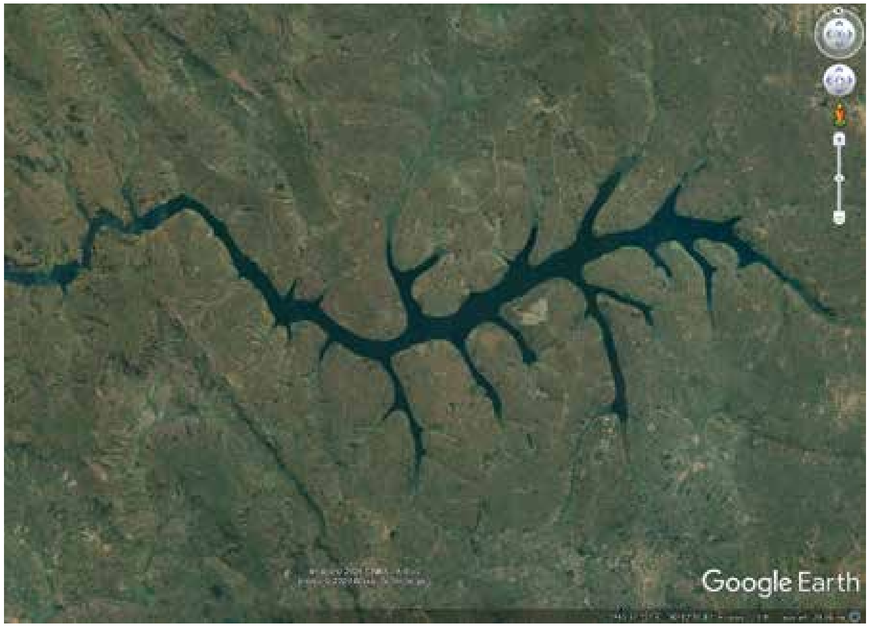
Note: The yellow arrow in the top image shows approximately where the field-level photo was taken.
Source: Google Earth (top) and Sumit Anand/WRI India (bottom).

Figure 18 | Comparison of Satellite Image (Top) and Corresponding Field-Level Image (Bottom) from the Chiluah Village of Sidhi, India, Showing Mix of Agriculture and Forest Land Use



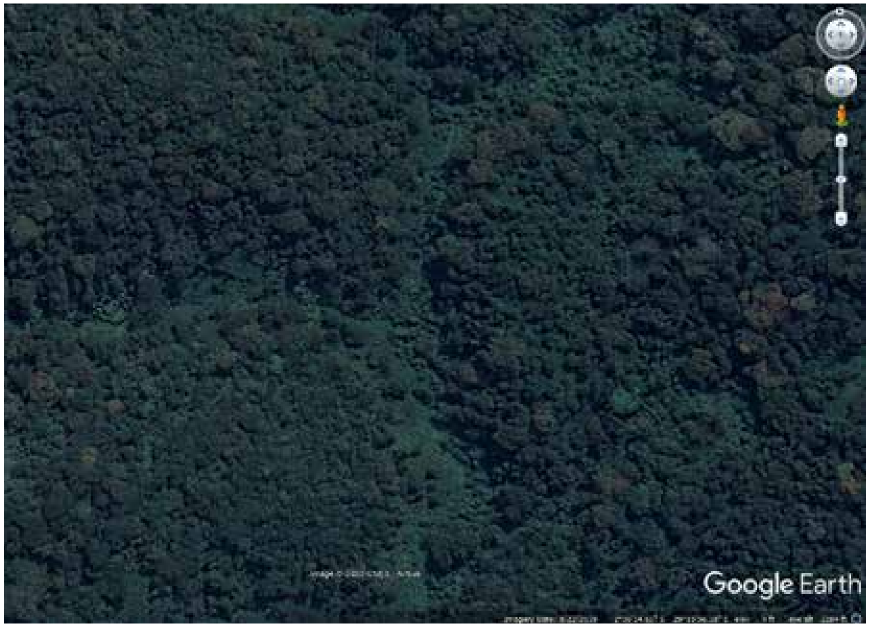
Note: The yellow arrow in the top image shows approximately where the field-level photo was taken.
Source: Google Earth (top) and Sandip Chowdhury/WRI India (bottom).

Figure 19 | Identifying Water Bodies (Image of Rwanda)



Source: Google Earth images.

Figure 20 | Identifying Non-dry Vegetated Areas (Image of Rwanda)



Source: Google Earth images.

Figure 19 provides an example of how **water bodies** appear in satellite imagery. They are often elongated, connected, and in shades of blue to dark green.

Tip: Provide a Reference Guide of Landscape Features

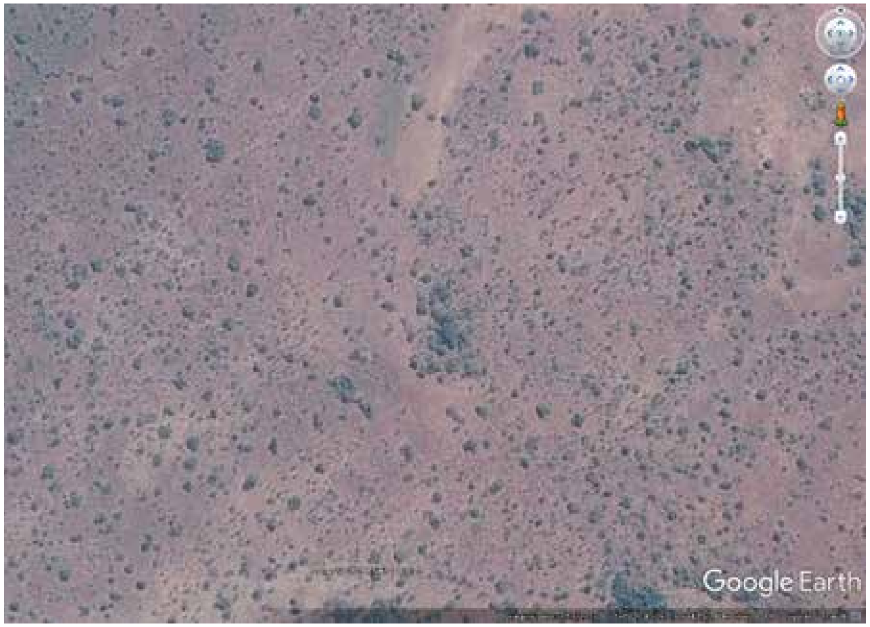
Providing a reference guide for different land use/land cover types or features—that includes multiple sample screenshots of each type and that data collectors can use as a reference throughout the mapathon—may help improve consistency in interpretation across data collectors, particularly for the more difficult features, such as shrubland and grassland. It may also be useful to highlight the Intergovernmental Panel on Climate Change (IPCC) land use classification hierarchy (Penman et al. 2003) to help data collectors determine the dominant land use in each plot. Showing example plots with different types of land uses with captions has proved to be very helpful for data collectors during assessments.

All **non-dry vegetated areas** in leaf-on conditions appear in shades of green. In Rwanda, most **forests are evergreen** (whether natural or plantations) and appear in shades of green to dark green, in different shapes and sizes (Figure 20). Depending on the canopy thickness, forest surfaces are smooth when trees and canopies are close together, and there is more texture where there are gaps in the canopy.

Tip: Use Input from the Data Collectors' Experiences as Part of the Visual Interpretation Training

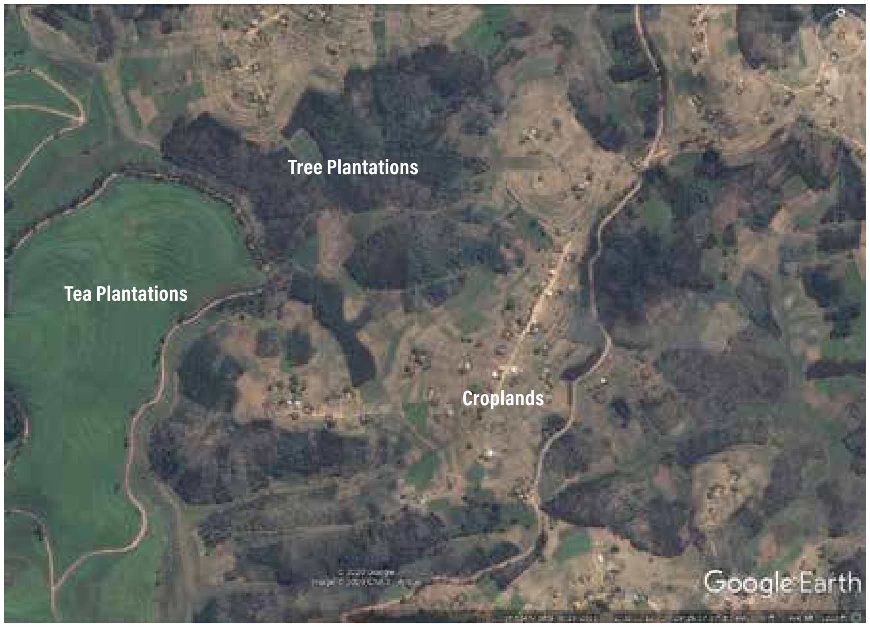
Training on imagery interpretation can be a participatory process where data collectors discuss and provide input on how to interpret various landscape features as part of the mapathon based on their experiences. This approach helps build consensus among the data collectors on how to interpret the imagery, which reduces bias due to the

Figure 21 | Identifying Shrubland Areas (Image of Rwanda)



Source: Google Earth images.

Figure 22 | Identifying Cultivated Vegetation (Image of Rwanda)



Source: Google Earth images.

subjectivity of individuals. It is worth noting that for any given mapathon there will be 15 to 25 individuals working on the same survey. It is possible that every member of the team could interpret the same object (e.g., tree or shrub) or land use type (e.g., cropland or grassland) slightly differently in a complex environment—and these differences can be exacerbated depending on the quality of the imagery available for the plot.

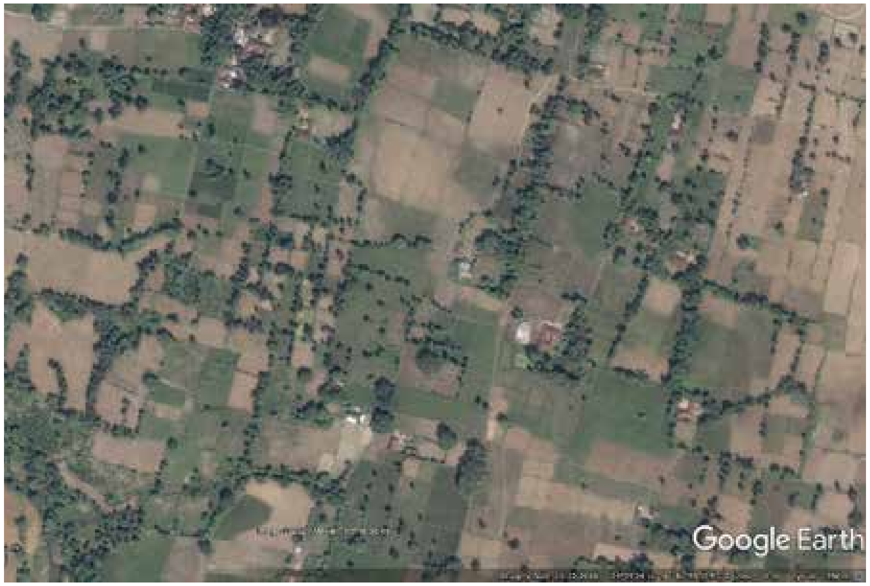
Shrubland and grassland (savanna) areas are also green but with more spacing between trees and variation in colors (see Figure 21). You will see individual trees or shrubs dispersed over grassy areas. Grasses also look green and smooth, or yellowish and smooth when dry. Sometimes it is hard to differentiate between grassland and shrubland because there are scattered trees in both land-use classes.

Most **cultivated vegetation** such as tea plantations and croplands have clear shapes, such as squares, rectangular parcels, or visible lines (Figure 22). They also appear in different colors depending on whether the vegetation is green or dry (i.e., fallow fields on the right side of the image look tan). These are signs that the land is used as cropland or plantation.

Tip: Compare Field-Level Photos with Satellite Imagery

If time and budget permit, an effective approach to training people on how to interpret satellite imagery is to pair a field-level photo of a landscape feature with satellite imagery of the same feature. As shown in Figures 17 and 18, this type of training was performed in Sidhi District, India. A direct comparison of these two perspectives provides a useful context for interpretation. Another approach is to conduct a field trip to a location within the area of interest and view satellite imagery of that location compared with what is seen in person.

Figure 23 | Identifying Trees on Boundaries (Image of Sidhi District, India)



Source: Google Earth images.

Trees on boundaries appear in a linear pattern on the boundaries of agricultural land. This is a common agroforestry practice in India (Figure 23).

8.2. COLLECT THE SURVEY DATA

The bulk of the mapathon is spent conducting the Collect Earth survey and collecting data for each sample plot. There will inevitably be questions that arise during the mapathon on how to interpret a sample plot or respond to a survey question; therefore, it is important to have a team of experts in the room to support the data collectors and help answer their questions. We recommend having a minimum of two Collect Earth experts, or one for every 10 data collectors, available throughout the mapathon to answer questions.

Tip: Create Overlapping Sample Plots between Data Collectors

Data collectors may still interpret the same land feature differently even with training and practice exercises. By ensuring that a certain percentage of plots to be surveyed are reviewed by multiple data collectors, differences between data collectors can be flagged and discussed during the mapathon, and the standard error can also be assessed. Reviewing the data after each day can also help mapathon managers identify data collectors that may need more training or practice.

8.3. CONDUCT A REAL-TIME ASSESSMENT OF DATA QUALITY

To improve the consistency and reliability of data as well as reduce the amount of time spent on quality control during the analysis phase, it is important to check the collected data while the mapathon is in progress to flag any obvious errors and work directly with data collectors to correct their errors and prevent future ones from occurring. Obvious errors to look for include typographical mistakes or inconsistencies in responses, such as a data collector identifying a sample plot's land use/ land cover type as "forest" but also responding that the area has 0 percent tree cover. Collect Earth automatically tags each sample plot with the name of the data collector who responded (this is established during the setup process for Collect Earth desktop and Collect Earth Online) and so you will be able to associate any errors with a particular data collector and address them with them directly.

As mentioned in Step 3, rules can be coded into the survey to prevent some errors from occurring. The level of effort required for quality assessment will depend on how many rules have been built into the survey (more rules reduce the likelihood of human error) and the complexity of the survey. Saiku (a data analysis software package that is integrated into Collect Earth) is a useful tool for identifying errors while the mapathon is in progress. At the end of each mapathon day, the data can be reviewed in Saiku to flag outliers, inconsistencies, or missing data. For example, statistics can be extracted such as average, maximum, and minimum percent tree cover per land use type. If there are any outliers, such as 90 percent tree cover on bare land, these can be flagged and double-checked by reassessing the sample plot. At a minimum, we recommend filtering out and identifying incomplete plots so that the data collectors can revisit those plots and complete the survey cards during the mapathon. An assessment of data quality for the full data compilation after the mapathon is complete is still needed (Step 7) but conducting a real-time assessment during the mapathon will make the post-processing step easier.

Tip: Emphasize Precision over Speed

There will likely be a discrepancy in speed and quality among data collectors. We recommend prioritizing data quality over speed of collection. In most cases, we have found that more data interpretation training is needed. To encourage standardization, provide definitions and examples. After the first day of the mapathon, you should have an estimate of the average number of plots classified per person and be able to estimate the average number of plots that can be assessed per person per day. With this information, you will know how long the entire data collection process should take. That said, it will be challenging to modify the duration of the mapathon once it is in progress, which is why we recommend testing your survey before it begins. Consistently encourage data collectors to focus on accuracy and precision to help reduce the time needed to fix data errors after the mapathon has ended.

Tip: Involve Participants in Data Quality Check and Verification

Use data quality check and verification as an opportunity to build participants' ownership of the quality of the data. You can also empower the data collectors to check their own work using a list of queries to catch common anomalies. Having data collectors conduct quality control initially for their own data has multiple observed advantages. Data collectors are more careful to not make mistakes as they will have to correct them, and their experience with cleaning data will prepare them for data analysis in Saiku. In Ethiopia, the experts checked the quality of their own data for a day by using Saiku to search for anomalies. For example, since the national definition of forest is a minimum canopy cover of 20 percent, they double-checked the plots outside of forest land use/land cover classes with more than 20 percent tree cover as well as plots inside of forest land use/land cover classes with less than 20 percent tree cover. They also double-checked plots with bunds/terraces where they didn't identify the presence of land treated with physical measures.

CHAPTER 8:

STEP 7: ASSESS DATA QUALITY

Assessing data quality is an important step following the conclusion of the mapathon event and involves reviewing the entire compilation of collected data for errors and making corrections to ensure a high standard of accuracy.

Once the mapathon is complete, the next step is to clean the data that were collected, which includes assessing data quality. This step involves reviewing the entire compilation of collected data for errors and making corrections in Collect Earth or using data analysis software (see references in the Further Reading section). Essentially, it is a more rigorous version of the real-time quality assessment described in Step 6. The main difference is that during this phase, any corrections will have to be made by the data analyst as opposed to the data collector.

Assessing data quality can be a time-consuming process but is essential for producing results that are as accurate as possible. Depending on the time and resources available as well as the goals of the survey, the main approach to addressing errors is to either reassess the sample plot or "throw out" the erroneous data point. While removing the data point is the quickest solution, that approach can cause problems with statistical bias if there are systematic errors, or statistical significance if the sample size becomes too small to produce representative results. However, sometimes poor image quality or other issues make a reassessment of the plot impossible.

Groundtruthing the data is also recommended for verifying the collected data. Groundtruthing means that a subset of the data collected via the mapathon is corroborated with what is seen on the ground during a field visit. It is also useful to use field visits to train data collectors on how to interpret satellite imagery before the mapathon begins. This approach was used in India's Sidhi District (see Case Study Highlight 8). Involving stakeholders and decision-makers in this process can help increase their confidence in the results and demonstrate the rigor of monitoring effort (see Case Study Highlight 9).

CASE STUDY HIGHLIGHT 8.

Groundtruthing in India’s Sidhi District

Field visits to Sidhi District were conducted by WRI India staff before and after the mapathon. Field visits before the mapathon observed common patterns of trees on agricultural lands and the local land use. Using GPS coordinates, Google Earth images were compared with photos from the field (see Figures 17 and 18). These observations were also used to help train data collectors during the mapathon and were especially useful for those with less experience assessing satellite imagery.

After the mapathon, substantial differences in land use/land cover area and distribution were found by comparing Collect Earth data to the official data from the National Remote Sensing Centre (NRSC). NRSC develops annual national land use/land cover maps through a supervised classification of Indian satellite data, “Resources at Advanced Wide Field Sensor,” using groundtruthed information. As a result, the team organized field visits for groundtruthing data from Collect Earth. Verification was carried out for 35 points across the seven administrative sections of the district. Data on tree cover, land use, agroforestry patterns, and species found in the landscape were recorded. This process found that the data from the mapathon were closer to the actual conditions than the official NRSC data. The primary difference was in the classification of land use. Local communities were practicing marginal farming on lands classified as wastelands (instead of croplands) by NRSC, meaning the land use of these areas did not show up as areas of farming on the official maps. The new information derived from the field visits led to the reclassification of these areas as croplands instead of wastelands, and thus enabled the team to recommend suitable restoration interventions for these areas based on the actual land use. For example, agroforestry and farmer-managed natural regeneration are recommended interventions for these areas that would increase tree cover in marginal croplands while strengthening the livelihoods of dependent communities.

CASE STUDY HIGHLIGHT 9.

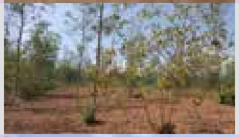
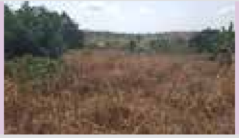
Groundtruthing in Rwanda's Gatsibo District

In the Gatsibo District of Rwanda, district government agronomists and monitoring and evaluation officers questioned whether satellite imagery interpretation would yield the same information as visiting the exact locations and observing what was there. As a result, the district forest officer accepted the invitation to participate in the groundtruthing and data verification processes to help the district team understand the capabilities and limitations of satellite imagery interpretation. The district forest officer, a GIS expert and NGO extension officer, completed groundtruthing in a day by comparing observations and photographs with Collect Earth data in 14 locations. All observations correlated with satellite imagery interpretation except in one location where satellite imagery interpretation was bare land and the observation reported a mix of grassland, bare land, and other land. Table 9 shows the results of groundtruthing compared with Collect Earth data in the 14 locations.

Three key lessons were learned from the groundtruthing exercise:

1. Involve local government in groundtruthing; in this case, their field-level participation provided them with a stronger connection to the monitoring process and increased their support for restoration by observing it first-hand. During our data validation workshop, local government officials iterated their interest in participating in groundtruthing. Those who did not attend were skeptical about the data while those who attended responded to the critiques by elaborating on their experiences and what they observed.
2. Create a process for selecting areas to groundtruth that will not require a potentially lengthy permit process to access. You can easily generate a random selection of plots to assess the accuracy of collected data using Collect Earth, but the produced plots need to be reviewed carefully to eliminate those where access would be limited due to required permits, such as national reserves, private land, and hard-to-reach areas. Note that eliminating plots due to cost or accessibility limitations has implications for the statistical validity of the accuracy assessment, so the trade-offs need to be carefully considered.
3. Increase the amount of training on how to interpret land use/land cover from satellite imagery at the beginning of the mapathon. Interpreting land use/land cover can be challenging even for an individual familiar with the landscape. Training that includes the field-level study of the different types of land use/land cover for the area of interest compared with their respective satellite images would be valuable, if time and resources allow, and would likely lead to improved outcomes between expected and observed results from groundtruthing.

Table 9 | A Subset of the 14 Groundtruth Observations Recorded in Rwanda

DATE	PLOT ID	FIELD PICTURE	TREE PRESENCE	TREES NO.	SHRUB PRESENCE	SHRUBS NO.	EXPECTED/ CE DATA	OBSERVED LAND COVER	DISTURBANCE	DISTURBANCE NOTES	LAND MGMT	LAND TENURE	PROJECT ACTIVITY
10-Aug-16	1		Yes	30	No	0	Settlement	Settlement	None		Unmanaged	Joint ownership	None
10-Aug-16	2		Yes	30	No	0	Cropland	Forest/ Cropland	None	None cropping	Agrosilvo pastoral	Private land	None
10-Aug-16	3		No	0	Yes	30	Grassland	Grassland	Other	Quarrying	Pastoral	Private land	None
10-Aug-16	4		No	0	No	0	Bare	Grassland/ Other land	Other	Quarrying	Pastoral	Private land	None
10-Aug-16	5		Yes	30	No	2	Cropland	Cropland	None	None	Agriculture	Private land other	None

Note: CE stands for Collect Earth.

Source: Authors.

CHAPTER 9:

STEP 8: ANALYZE DATA AND PRESENT RESULTS

It is important to communicate the results from a Collect Earth mapathon clearly so that the target audience can use the data to inform key decisions related to restoration and land use planning. Referring to the data use plan and engagement strategy from Step 1 will help you to identify the statistics and presentation formats to focus on.

The amount of data collected during a mapathon and the many ways to analyze data can feel overwhelming at first. During this step, it is important to refer to your data use plan and influence strategy (Step 1), which outlines your goals and target audience for communicating your results, to anchor your data exploration and analysis.

For example, if your objective is to communicate to a district planning officer the district's progress on implementing restoration interventions to achieve an average of 10 percent tree cover on croplands, which statistics would be important to show, and which format would tell that story in a compelling way? In this example, you could generate maps showing the distribution of tree cover on croplands across the district, as well as statistics and graphs showing whether the target has been met and, if not, where there are opportunities to increase tree cover.

10.1. GENERATE STATISTICS AND GRAPHS

Saiku and Microsoft Excel pivot tables are the most common data analysis software packages for generating statistics and graphs using Collect Earth data. Summarizing the data by administrative jurisdiction and providing averages or totals for the entire area of interest are the most common ways to present results. When using the results to recommend interventions, it is important to consider the goals of the mapathon. For example, if the goal was to assess the status of tree cover outside of forests, it is often useful to report average tree cover per land use type, such as tree cover in settlement areas or on croplands. Table 10 provides some examples of common statistics, charts, and graphs that are produced using Collect Earth data.

Whether the summary statistics are presented as a simple number, table, bar chart, pie chart, or other type of visual tool will depend on which results you are presenting, your mode of communication (e.g., report, PowerPoint presentation), and the target audience. This section includes a few examples of how the results were presented in all of the case study countries—Rwanda, El Salvador, Ethiopia, and India—in Case Study Highlights 10–13.

Table 10 | Examples of Statistics and Visualizations to Produce Using Collect Earth Data

CATEGORY	STATISTIC
Land use/ land cover	Percent land use/land cover per type
	Change in percent land use/land cover per type over time
Tree cover	Average percent tree cover
	Change in percent tree cover over time
	Average percent tree cover per land use/land cover type
	Change in percent tree cover per land use type over time
	Number of hectares with tree cover loss
	Number of hectares with tree cover gain

Note: CE stands for Collect Earth.
Source: Authors.

CASE STUDY HIGHLIGHT 10.

Presenting Results in Rwanda's Gatsibo District

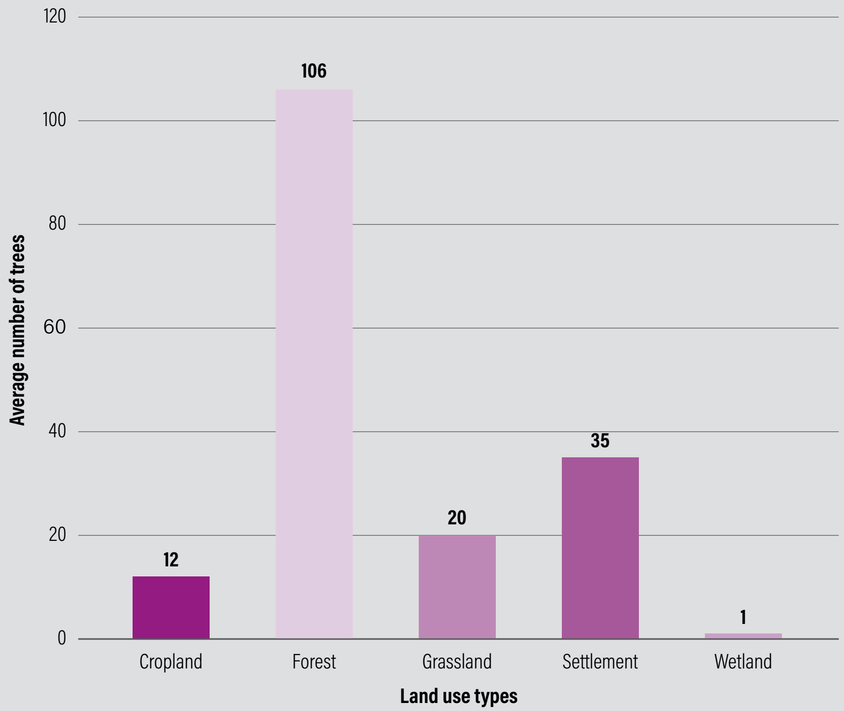
In Rwanda's Gatsibo District, the main objectives of the mapathon were to create a baseline of tree cover for the district and support the district planning process by showing where there was an opportunity to increase forest cover to achieve a goal of 30 percent coverage across the district (where "forest" is defined as 0.25 hectares with trees higher than 7 m and crown cover of 10 percent). To meet these objectives, the following analyses and statistical summaries were produced:

- Average number of trees per hectare by land use/land cover type
- Average number of trees per hectare by administrative sector
- Sectors with a lower than average number of trees per hectare
- Percent tree cover by land use/land cover type
- Land use/land cover change between 2006 and 2014

Visualizations of a few of these statistics are shown in the following figures.

The graph in Figure 24 shows that, outside of forests, there are surprisingly more trees per hectare around homes and grasslands than on croplands, signaling that there is an opportunity to plant trees on farms and agricultural lands if soil and climate permit.

Figure 24 | Average Number of Trees per Hectare by Land Use in Gatsibo



Source: WRI 2018.

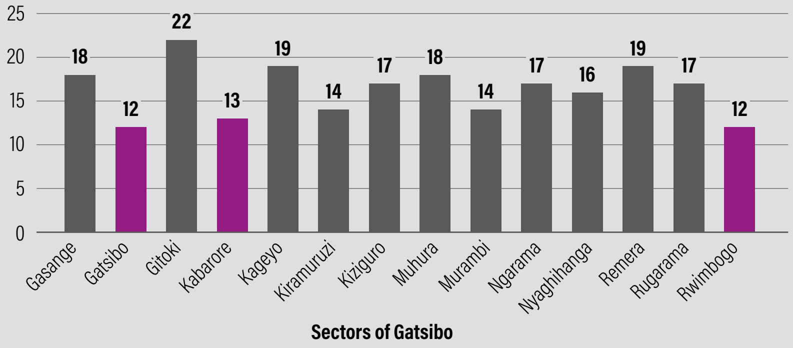
CASE STUDY HIGHLIGHT 10, CONTINUED.

Presenting Results in Rwanda's Gatsibo District

Figure 25 shows the average percent tree cover for the sectors (the sub-administrative unit) within Gatsibo District; the average percent tree cover across all sectors is 14 percent. Those that have a percent tree cover below the district-wide average are highlighted in purple.

As shown in Figure 26, from 2006 to 2014 the majority of land in Gatsibo District was converted from forests, grasslands, wetlands, and shrublands to cropland or settlements.

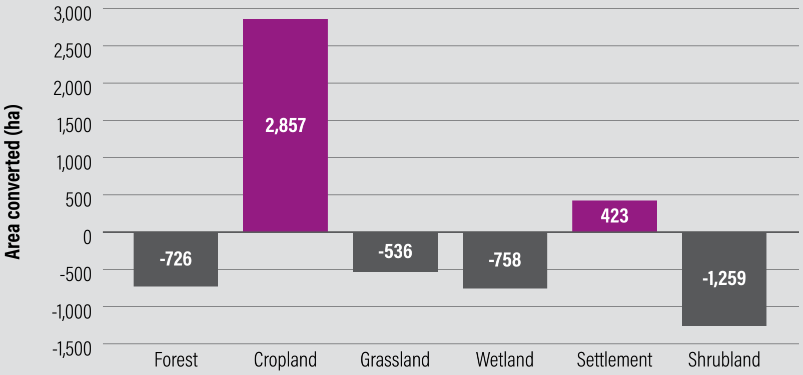
Figure 25 | Average Percent Tree Cover per Hectare per Sector of Gatsibo District across All Land Use Types



Note: The average across sectors is 14. Red bars represent below average tree cover.

Source: WRI 2018.

Figure 26 | Change in Land Use/Land Cover Area between 2006 and 2014 in Gatsibo District



Note: Ha stands for hectares.

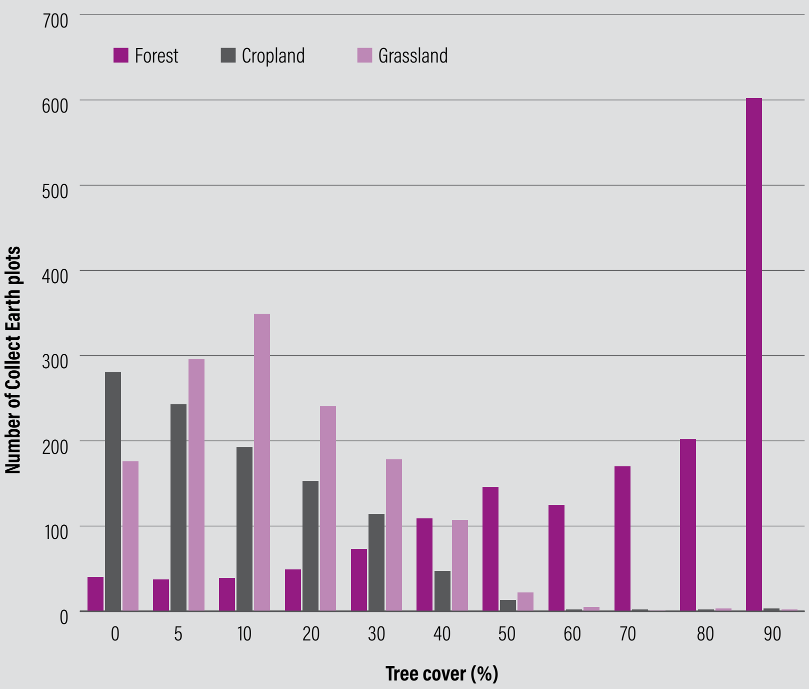
Source: WRI 2018.

CASE STUDY HIGHLIGHT 11.

Presenting Results in El Salvador's Cerrón Grande Watershed

For El Salvador's Cerrón Grande watershed, one of the objectives was to create a baseline estimate of tree cover to support planning for interventions to increase tree cover. Figure 27 shows the percentage of tree cover in three land use/land cover types: cropland, grassland, and forest. The graph highlights the number of plots that fall into various tree cover classes and the associated trend lines. The greatest number of cropland plots have 0 percent tree cover, and so the yellow trend line skews from left to right—as tree cover increases, the number of cropland plots in that tree cover class decreases. For grasslands (light purple), the greatest number of plots have 10 percent tree cover, and so the trend line peaks at this tree cover class, and decreases as tree cover increases. For forests (dark purple), the lowest tree cover classes are considered "understocked," or sparse, with the majority of plots having at least 90 percent tree cover.

Figure 27 | Tree Cover in Different Land Uses in the Cerrón Grande Watershed



Note: CE stands for Collect Earth.

Source: Authors.

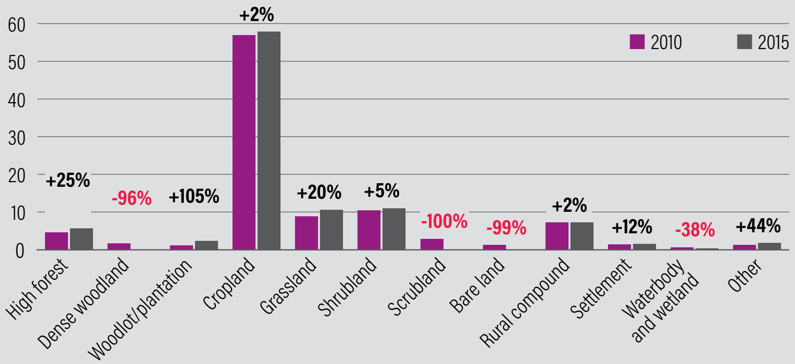
CASE STUDY HIGHLIGHT 12.

Presenting Results in Ethiopia's Sodo Guragie Woreda

One of the main objectives of the mapathon in Sodo Guragie was to track progress toward tree cover targets for the woreda. By collecting data from two years, 2010 and 2015, graphs could be generated that illustrate the trend toward these targets and whether they are on track. For example, Sodo Guragie set a target of 19 percent forest cover in the woreda's Growth and Transformation Plan I. Figure 28 shows that, based on the collected data, the forest cover (high forest, dense woodland, and woodlot/plantation combined) was 8.1 percent in 2015, which shows a positive trajectory from a 7.5 percent baseline in 2010, but still falls short of the target of 19 percent (EFCCC 2020).

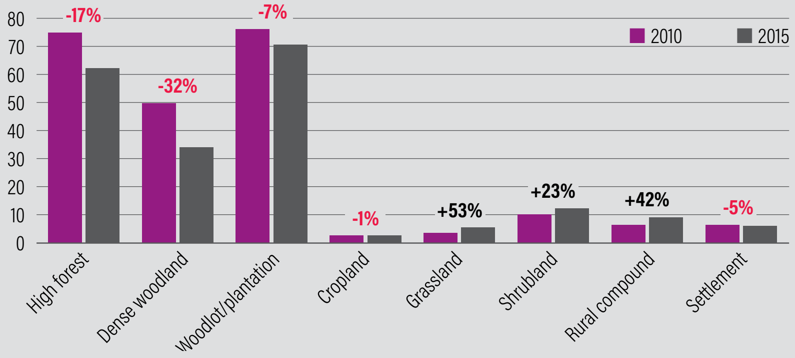
Viewing the data in a slightly different way by looking at average percent tree cover per land use/land cover type shows more nuance in terms of change in tree cover over time. These data show that, in areas where land use/land cover type has remained the same, the percent of tree cover per type may have changed. For example, Figure 29 shows that average percent tree cover in high forest and dense woodland has decreased over the five-year period (changes in percent tree cover in woodlot/plantation reflect harvesting and production cycles and therefore do not provide much insight). The downward trend in percent tree cover in high forest and dense woodland is a sign of forest degradation, which dampens the slight upward trends in forest area observed in Figure 28 (EFCCC 2020).

Figure 28 | Percent Land Use/Land Cover Type and Relative Change between 2010 and 2015



Note: Relative change is the change from 2010 to 2015 reported as a percentage of the value for 2010.
Source: EFCCC 2020.

Figure 29 | Average Percent Tree Cover per Land Use/Land Cover Type (2010–15) and Relative Change



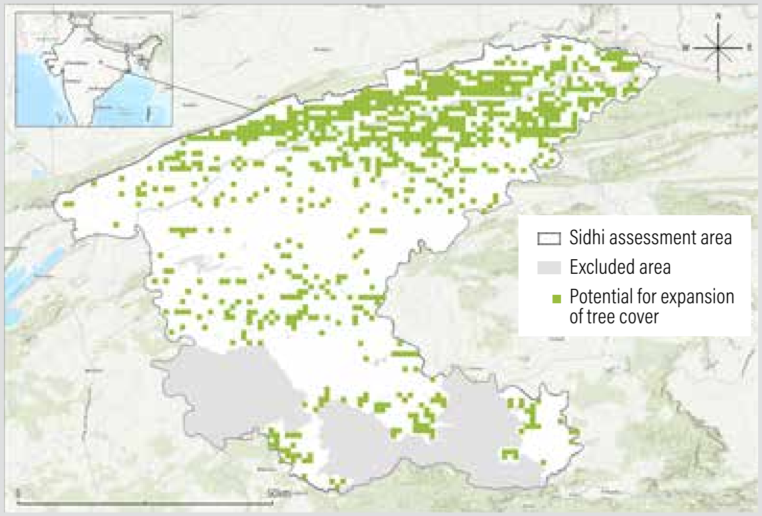
Note: Relative change is the change from 2010 to 2015 reported as a precentage of the value for 2010.
Source: EFCCC 2020.

CASE STUDY HIGHLIGHT 13.

Presenting Results in India’s Sidhi District

In Sidhi District, one of the primary objectives of the mapathon was to assess the extent of existing tree-based interventions on farmlands and make recommendations for where more tree-based interventions could be implemented. To communicate these results most effectively, maps were created to show the extent of existing interventions and showcase where there was potential for additional interventions. In these maps, the Collect Earth sample plots were imported using GIS software (e.g., ArcMap, QGIS); tree-based interventions on farmland—trees on bunds and dispersed trees—and other interventions were plotted (Figure 30, top). Similarly, plots were classified into types of agroforestry practices—horticulture, silviculture, and silvi-horticulture—based on the tree species identified by the participants (Figure 30, bottom). The data showing existing tree cover of less than 40 percent were plotted to create a map highlighting where there was potential to increase on-farm tree cover (Figure 31).

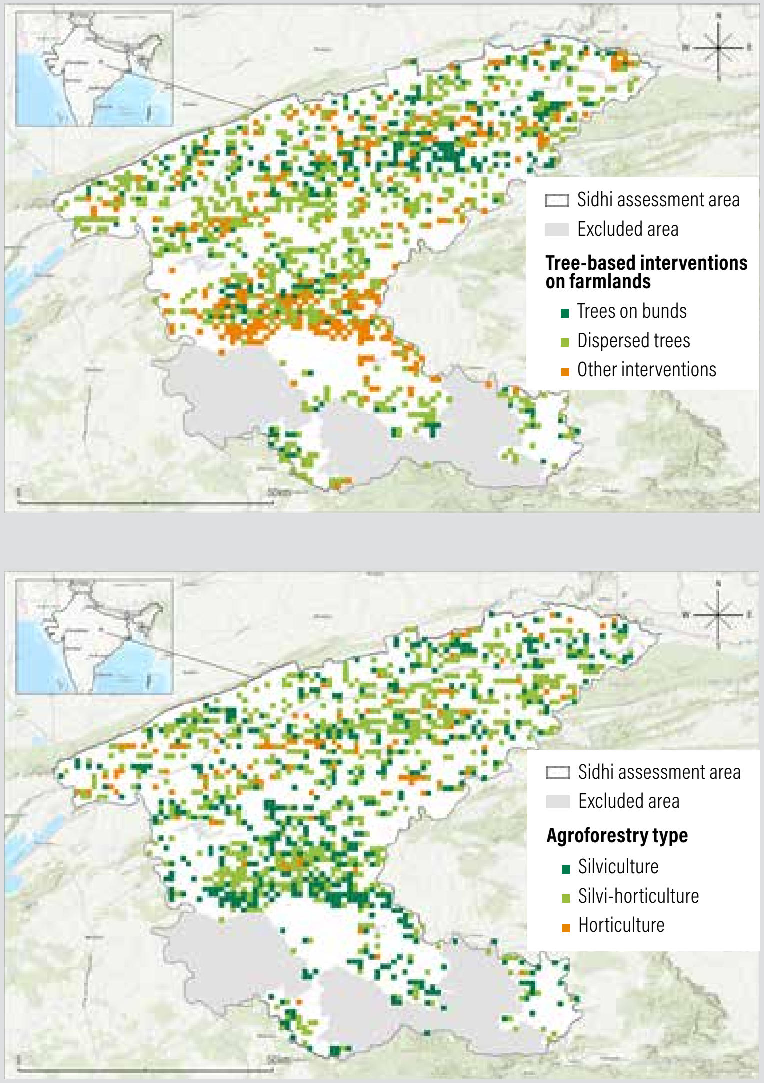
Figure 31 | Potential to Increase Tree Cover on Farmlands in Sidhi District, India



Sidhi assessment area
Excluded area
Potential for expansion of tree cover

Source: Map produced at WRI using data from Survey of India, authors, and Esri.

Figure 30 | On-Farm Tree-Based Interventions in Sidhi District, India



Sidhi assessment area
Excluded area
Tree-based interventions on farmlands
Trees on bunds
Dispersed trees
Other interventions
Sidhi assessment area
Excluded area
Agroforestry type
Silviculture
Silvi-horticulture
Horticulture

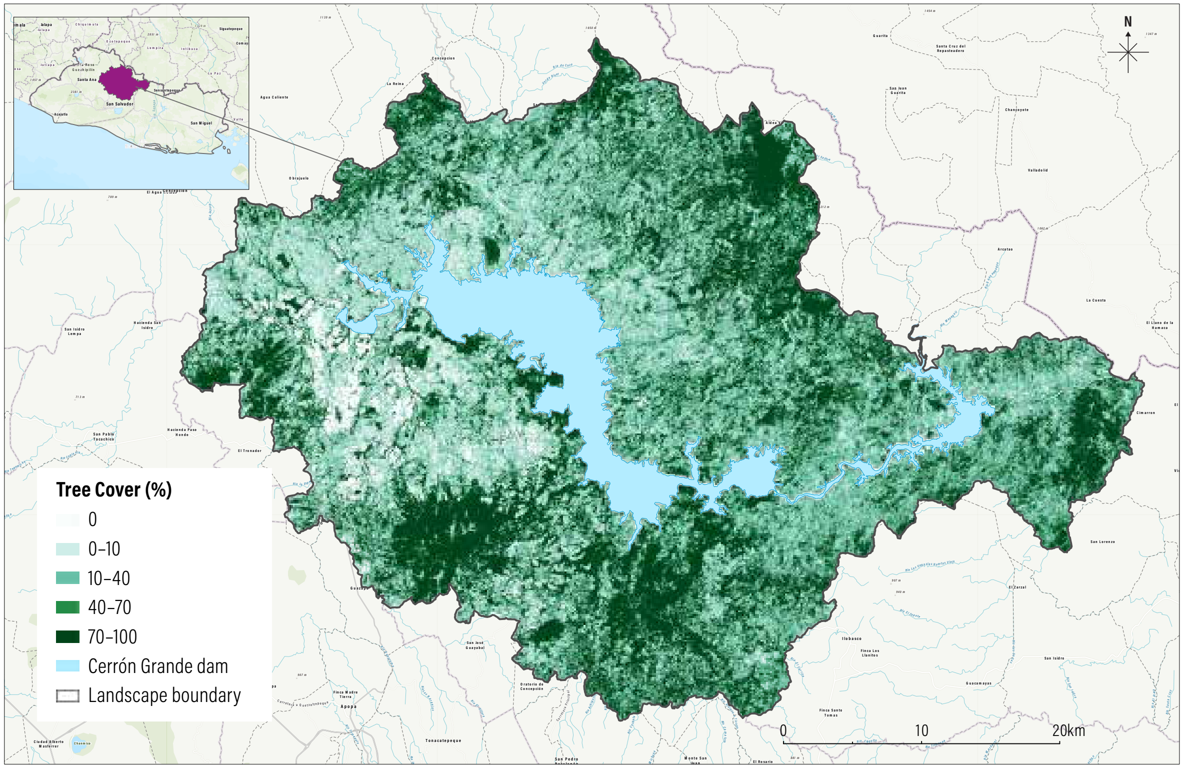
Source: Map produced at WRI using data from Survey of India, authors, and Esri.

10.2. GENERATE MAPS USING COLLECT EARTH DATA

Maps are a powerful way to present the information generated from a Collect Earth mapathon. There are multiple ways of presenting Collect Earth data on a map, the simplest of which is to display the sample plots themselves, classified according to one of the variables that were collected, as shown in Figures 30 and 31. These types of maps are most useful when a systematic sampling approach is used as the maps evenly distribute the data across the full area of interest.

Another approach to mapping is developing wall-to-wall land-cover and tree-cover maps using SEPAL or Google Earth Engine. In the Google Earth Engine approach, one would use the Collect Earth data to train the classification algorithm of your choice, which will accordingly assign the pixels (unsampled areas) into one of the land use/land cover types even if that pixel was not part of the Collect Earth sampled plots. For example, imagery classified as cropland using Collect Earth has a certain spectral signature value. The trained algorithm can use the information stored in the memory from training to remember and classify new pixels of imagery with similar spectral signatures as "cropland," even if the pixels are outside of the sample area. Thus, these maps are called "wall-to-wall" when they are made for the full study area. An example of a wall-to-wall tree cover map for Cerrón Grande watershed, El Salvador, is shown in Figure 32. The detailed methodology for this is beyond the scope of this publication; however, if interested, please refer to recommended reading such as Jensen (2016) or Lillesand et al. (2015).

Figure 32 | Wall-to-Wall Tree Cover Map for Cerrón Grande Watershed, El Salvador



Note: This map of percent tree cover was created using a wall-to-wall mapping method and was produced as an output of the Collect Earth mapathon in Cerrón Grande watershed, El Salvador.

Source: Map produced at WRI using data from authors, IGCN, and OpenStreetMap.

CONCLUSION

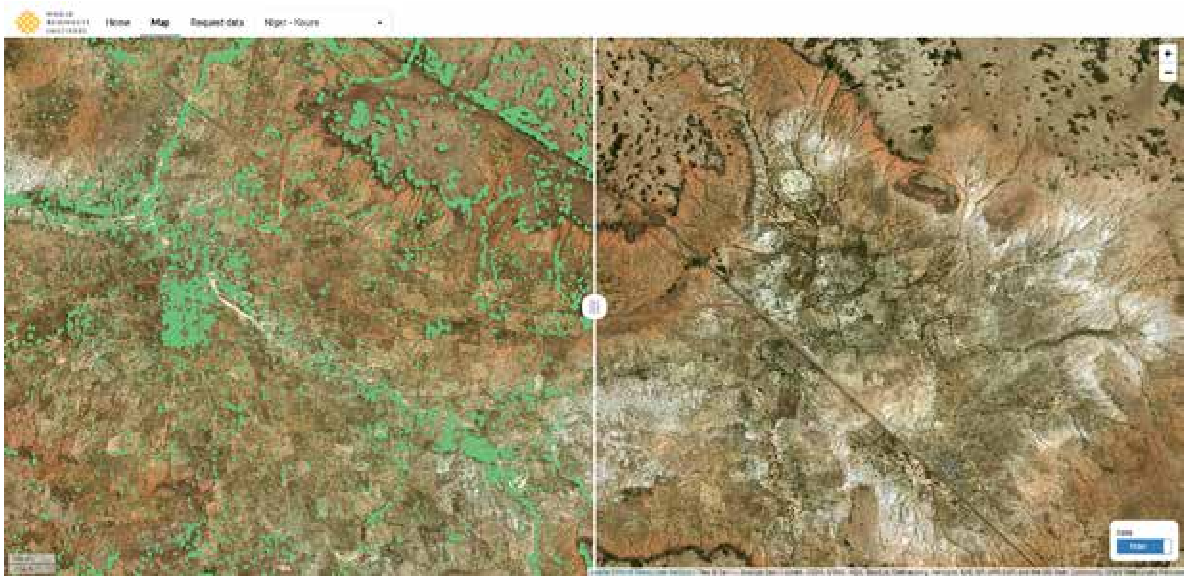
Data from a Collect Earth mapathon can provide the evidence needed to understand whether restoration goals are on track or what needs to be done differently to stay on track. Restoration monitoring is a quickly developing field of research, with advances in technology rapidly changing the landscape of how monitoring is best approached. The framework presented in this guide is newly derived from the authors' recent experiences and will be revisited in the future as more lessons are learned.

Monitoring is an essential step in building a restoration movement, but it is about more than collecting data and producing maps. A monitoring program is most effective when it is integrated into a larger restoration framework, which includes multiple stakeholders in a landscape identifying shared goals for restoration; planning and implementing restoration activities that will strengthen the ecosystem as a whole; and monitoring progress of the collective framework. In this context, monitoring data from Collect Earth mapathons can provide the evidence needed to understand whether the goals are on track to being achieved, or what needs to be done differently to stay on track. To harness the full potential of restoration monitoring, it is important to acknowledge that monitoring is a long-term commitment, just like restoration itself. Setting targets and baselines is only the beginning; they require follow-up at regular intervals to identify the progress that has been achieved and adaptively manage the interventions.

The framework for planning and conducting a Collect Earth mapathon outlined in this report is newly derived from the authors' recent experiences, and thus will benefit from further testing and application to refine the approach. For instance, applying this framework to future Collect Earth mapathons and conducting focus group discussions with the project team to identify what did or did not work well would help us identify if there are any steps that need further elaboration or activities that are not captured in the eight steps. Given that Collect Earth is, at present, one of the most viable options for monitoring restoration, we anticipate there being many opportunities to further apply and refine the approach.

Another important consideration for monitoring restoration is the transparency of data and communication of results. While this guidebook focuses on presenting results that were tailored to specific stakeholders and decision-makers who have the most influence on restoration planning and outcomes, it is also important to consider sharing the data as widely as possible so that anyone with a vested interest in the landscape can access the information. Sharing these stories—either success or failure—enables

Figure 33 | Restoration Mapper Uses Collect Earth Online and Machine Learning



Note: This is a screenshot of the high-resolution data used to create the Restoration Mapper prototype, which displays detailed, wall-to-wall maps of the spatial distributions of trees with canopy diameters larger than three meters (m). The maps are created using artificial intelligence algorithms and freely available 10-m-resolution Sentinel-2 satellite data (not shown here). The image on the left shows the pixels of tree cover generated from the 10-m-resolution imagery, and the image on the right shows a basemap layer of high-resolution satellite imagery for context.
Source: Brandt and Stolle 2021.

valuable lessons to reach those working in the restoration space and improves outcomes more broadly. One way of sharing this information is through interactive maps, where data can be stored, summarized, and visualized geographically to provide clear indication of progress. One example of such a platform is the Restoration Monitoring Atlases, where data from restoration monitoring activities in Rwanda, Kenya, El Salvador, Honduras, and Nicaragua provide case studies in how stakeholders are demonstrating progress on their restoration goals.

The technology and innovations in remote sensing science continue to develop at a fast pace, and so too the protocols for monitoring restoration will need to adapt to leverage these advances. For instance, new methodologies that integrate human-annotated data, such as from Collect Earth, with remote sensing classification methods are under development (Reytar et al. 2020). Restoration Mapper, for example, uses Collect Earth Online's capacity to label samples combined with artificial intelligence algorithms and freely available 10-m-resolution Sentinel-2 satellite data to create detailed, wall-to-wall maps of the spatial distributions of trees with canopy diameters larger than 3 m (Figure 33). The combination of a sampling approach and machine learning enables the rapid assessment of tree density in non-forested landscapes with greater than 95 percent accuracy. Based on the nature of tree distributions, the technology can be used to identify agroforestry areas, riparian buffer zones, and crop buffer zones (Brandt and Stolle 2021).

This guide provides a framework for how to monitor restoration using recommended tools and methods that are available now—given that time is of the essence in beginning a restoration monitoring program—and will be revisited in the future as more lessons are learned.

FURTHER READING

The following reference materials provide additional context and guidance on many of the mapathon components and related tools discussed in this guidebook. The references are organized according to the most relevant step in the mapathon process.

Developing a data use plan and engagement strategy (Step 1):

- *A Guide to the Restoration Opportunities Assessment Methodology (ROAM)* manual defines the elements of a forest and landscape restoration strategy and can support the process of identifying key stakeholders and influence targets (IUCN and WRI 2014).
- *The Restoration Diagnostic: A Method for Developing Forest Landscape Restoration Strategies by Rapidly Assessing the Status of Key Success Factors* provides a structured method for identifying the enabling conditions and barriers to successful restoration programs, illustrated with case studies from around the world (Hanson et al. 2015).
- *Mapping Social Landscapes: A Guide to Identifying the Networks, Priorities, and Values of Restoration Actors* provides a method for identifying key restoration actors in the landscape that will support the development of a more targeted influence strategy (Buckingham et al. 2018).

Defining the survey indicators and area of interest (Step 2):

- *The Road to Restoration: A Guide to Identifying Priorities and Indicators for Monitoring Forest and Landscape Restoration* provides a framework for identifying which indicators to include in your Collect Earth survey (Buckingham et al. 2019).
- *The Sustainability Index for Landscape Restoration* provides an example of how indicators were selected and compiled for a case study watershed in El Salvador (Zamora Cristales et al. 2020).

Designing the survey and sampling scheme and general guidance on Collect Earth (Steps 3 and 4):

- The Open Foris website (openforis.org) provides a comprehensive set of guidance materials on how to use Collect Earth and the related suite of tools, including user manuals and tutorials, as well as links to download each tool. Direct links to each tool are also provided here:
  - Collect: http://www.openforis.org/tools/collect.html
  - Collect Earth: http://www.openforis.org/tools/collect-earth.html
  - Collect Earth Online: http://www.openforis.org/tools/collect-earth-online.html
  - SEPAL: http://www.openforis.org/tools/sepal.html
- *Remote Sensing* journal article "Collect Earth: Land Use and Land Cover Assessment through Augmented Visual Interpretation" (Bey et al. 2016): https://www.mdpi.com/2072-4292/8/10/807.
- FAO's *Map Accuracy Assessment and Area Estimation: A Practical Guide* (FAO 2016): http://www.fao.org/3/a-i5601e.pdf.

Organizing and conducting the mapathon (Steps 5 and 6):

- The U.S. National Aeronautics and Space Administration (NASA) offers tips and strategies for interpreting a wide variety of images here: http://earthobservatory.nasa.gov/features/ColorImage.

Assessing data quality (Step 7):

- Saiku is an open-source data analysis software program that can support data quality assessment: http://www.openforis.org/tools/collect-earth/tutorials/saiku.html.
- FAO offers guidance in its user-friendly guide *Map Accuracy Assessment and Area Estimation: A Practical Guide* (FAO 2016): http://www.fao.org/3/a-i5601e.pdf.
- Olofsson et al. (2014) highlight good practices in a *Remote Sensing of Environment* article, "Good Practices for Estimating and Assessing Accuracy of Land Change": http://reddcr.go.cr/sites/default/files/centro-de-documentacion/olofsson_et_al._2014_-_good_practices_for_estimating_area_and_assessing_accuracy_of_land_change.pdf.

Analyzing data and presenting results (Step 8):

- This scientific study on the extent of forest in dryland biomes provides an example of how large-scale data sourced from Collect Earth can be analyzed and presented (Bastin et al. 2017): https://science.sciencemag.org/content/356/6338/635.
- The Bonn Challenge Barometer (https://infoflr.org/bonn-challenge-barometer/) provides an example of a holistic monitoring framework and shows how Collect Earth mapathon data could be integrated and presented to show progress on international restoration commitments.

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ACKNOWLEDGMENTS

We extend special thanks to the funder of this publication, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) of Germany.

The authors are grateful to the following peers who provided critical reviews and helpful suggestions to this guidebook: Liz Bourgault (WRI), Achille Djeagou Tchoffo (WRI), Maria Franco Chuaire (WRI), Eric Mackres (WRI), Marcelo Matsumoto (WRI), Mikaela Weisse (WRI), Gregory Taff (WRI), Ruchika Singh (WRI), James Daniel (REGID International), Honore Niyongsenga, Joseph Njue (IUCN), Paula Andrea Paz (International Center for Tropical Agriculture), Karis Tenneson (Spatial Informatics Group), Karen Dyson (Spatial Informatics Group), Kathleen Buckingham (WRI), Beth Kaplin (University of Rwanda), Julian Fox (FAO), Christophe Besacier (FAO), Prabhakar Rajagopal (Strand Life Sciences), Alfonso Sánchez-Paus Díaz (FAO), and Sunny Qiao (WRI).

The authors would also like to thank the contributors to the Collect Earth mapathons that make up our four country case studies:

El Salvador: The mapathon workshops for the Cerrón Grande watershed were performed in San Salvador in 2017. The workshops were hosted by the Ministry of Environment and Natural Resources (MARN) and co-organized by WRI and PRISMA Foundation. Participants included representatives of different agencies of the Ministry of Environment and Ministry of Agriculture in El Salvador, as well as a delegation from the Ministry of Environment from Honduras. This effort was developed thanks to the leadership of Jorge Quezada and Giovanni Molina from MARN, El Salvador. We are also grateful for the support from Lucio Santos and Carla Ramirez from FAO for their advice as we prepared for the mapathon, as well as Abner Jimenez from the Gesellschaft für Internationale Zusammenarbeit (GIZ) regional office for Central America and the Dominican Republic. We extend special thanks to the funder of this project, BMU of Germany.

Ethiopia: Under the leadership of the Environment, Forest and Climate Change Commission (previously Ministry), and with the technical support of World Resources Institute, experts from many organizations helped develop Ethiopia's Tree Assessment Survey and collect data for the two pilot woredas (Sodo Guragie in SNNP Regional State and Meket in Amhara Regional State) from which lessons learned inform this report. These institutions are Sodo Office of Environment and Forest; Sodo Office of Agriculture and Natural Resources; World Vision; SOS Sahel Ethiopia; Institutional Strengthening for the Forest Sector Development Program (Sodo Guragie, Meket, and federal level); SNNP Regional State Bureau of Agriculture and Natural Resources; SNNP Regional State Environment Protection and Forest Authority; Gurage Zone Environment Protection and Forest Authority; Siltie Zone Environment Protection and Forest Authority; SNNP Regional REDD+ Coordination Unit; Wondo Genet College for Forestry and Natural Resources; Meket Agriculture Office; Meket Environmental Protection, Land Administration and Use Office; Amhara National Regional State Environment; Forest and Wildlife Protection and Development Authority; Amhara Regional REDD+ Coordination Unit; Organization for Rehabilitation and Development in Amhara (ORDA); Amhara Forest Enterprise; Abbay Basin Authority; Amhara National Regional State Bureau of Agriculture; Amhara National Regional State Bureau of Agriculture; Bahir Dar University; Debre Tabor University; Ministry of Agriculture and Livestock (previously Ministry of Agriculture and Natural Resources); Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); Ethiopian Geospatial Information Agency (previously Ethiopia Mapping Agency); Environment and Climate Research Center/Ethiopian Development Research Institute; and UN Food and Agriculture Organization Ethiopia. We would like to thank the funders that contributed to this project: the Norwegian International Climate and Forest Initiative (NICFI) as part of the Royal Norwegian Ministry of Climate and Environment, the Federal Ministry for Economic Cooperation and Development of Germany (BMZ), and the Global Environment Facility (GEF) project "Building the Foundation for Forest Landscape Restoration at Scale" with implementation support from the United Nations Environment Programme.

India: The case study from Sidhi District, India, draws on lessons learned from the mapathon conducted as part of the assessment of restoration opportunity in the district. WRI India is thankful to the Bankers Institute of Rural Development in Lucknow for hosting the Collect Earth Mapathon. The authors acknowledge with gratitude the support and participation of local stakeholders from Sidhi including Rajiv Singh Chauhan, Surya Singh Pal Ranjan, Chandra Prakash Gupta, Vikram Singh, Nagendra Singh, Shubam Gupta, Babulal Kol, and Ravindra Singh for their valuable insights during the mapathon. The authors are thankful for the contribution of GIS experts Sukanya Saikia, Raees Ahmad Wani, Siddhartha Jain, Shailendra Kumar, Meghna Joshi, Komal Daal, Sara Bine Ali, Parth, and Shubham Dwivedi who ably facilitated data collection during the mapathon. The authors are also thankful to Dr. Rohini Chaturvedi and Mr. K K Singh for their guidance in designing and conducting the mapathon. We duly acknowledge the support of Sandip Chowdhury, Sumit Anand, Dhanapal Govindarajulu, Jayant Karmarkar, Dr. Ruchika Singh, and Sidhtharthan Segarin for their contributions in designing and organizing the mapathon and analyzing the data. The authors express their gratitude to Alfonso Sánchez-Paus Díaz for his technical support on Collect Earth. The mapathon was conducted with funding from the Global Environment Facility (GEF) project "Building the Foundation for Forest Landscape Restoration at Scale" with implementation support from the United Nations Environment Programme.

Rwanda: Under the leadership of the Ministry of Environment, and with the technical support of World Resources Institute, experts from many organizations contributed their time and knowledge to support the authors in developing this guidebook, as well as collecting and validating data for Gatsibo District (the case study featured in this report), Gicumbi District, and Rulindo District. These institutions are the Rwanda Water and Forestry Authority (RFA), Gatsibo District Office, Gicumbi District Office, Rulindo District Office, University of Rwanda's College of Science and Technology, UN Food and Agriculture Organization Rwanda, International Union for Conservation of Nature (IUCN), World Agroforestry, World Vision, Albertine Rift Conservation Society, and Vi Agroforestry. We would like to reserve special thanks to the University of Rwanda's College of Science and Technology for hosting the first-ever Collect Earth mapathon in Rwanda, and we are particularly grateful for the assistance given by the faculty, students, and volunteers. We would like to express our great appreciation to mapathon champions Felix Rurangwa (RFA) and Charles Karangwa (IUCN), and to our trainers Bernadette Arakwiye (WRI), Tesfay Woldemariam (WRI), Anne-Maud Courtois (FAO), and Joseph Njue (IUCN). Last but not least, we wish to acknowledge the following individuals for their time and efforts in collecting data: from RFA: Anastase Nyandwi, Alpha Jean Bosco Mbarushimana, and Honore Niyonsenga; Gatsibo District: Sylvere Namuhoranye; IUCN: Donatha Dukuzumuremyi and Jean Pierre Maniriho; University of Rwanda-Centre for GIS and Remote Sensing: Joseph Tuyishimire, Djuma Nsanzimana, and Odette Nishimwe; University of Rwanda-Nyagatare Campus Campus: Assumpta Uwamariya, Claudien Rukundo, Alex Mupende, Florence Nirere, Augustin Rukundo, Geofrey Kavutse, Dieudonne Nshimyimana, William Gatera, Steven Mwesigye, Theogene Ntirenganya, Ester Mutoni; University of Rwanda College of Science and Technology: Obed Tuyizere; University of Rwanda-Huye Campus: Aloysie Manishimwe; and Albertine Rift Conservation Society: Jean Ndamage. This project was made possible with funding from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany (BMU) and Norway's International Climate and Forest Initiative (NICFI) as part of the Royal Norwegian Ministry of Climate and Environment.

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ABOUT FAO

The Food and Agriculture Organization (FAO) is a specialized agency of the United Nations that leads international efforts to defeat hunger.

Our goal is to achieve food security for all and make sure that people have regular access to enough high-quality food to lead active, healthy lives. With over 194 member states, FAO works in over 130 countries worldwide.

ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

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Required citation: FAO and WRI. 2021. *Mapping together—A guide to monitoring forest and landscape restoration using Collect Earth Mapathons*. Rome, Washington, DC. FAO and WRI. https://doi.org/10.4060/cb2714en

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ISBN 978-92-5-133823-0 [FAO]

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ISBN 978-92-5-133823-0
CB2714EN/1/01.21